# An Action Plan in Response to Coded Wire Tag (CWT) Expert Panel Recommendations

A Report of the Pacific Salmon Commission CWT Workgroup

March 2008

**Pacific Salmon Commission**
**Technical Report No. 25**

The Pacific Salmon Commission is charged with the implementation of the Pacific Salmon Treaty, which was signed by Canada and the United States in 1985. The focus of the agreement are salmon stocks that originate in one country and are subject to interception by the other country. The objectives of the Treaty are to 1) conserve the five species of Pacific salmon in order to achieve optimum production, and 2) to divide the harvests so each country reaps the benefits of its investment in salmon management.

Technical Reports of the Pacific Salmon Commission present results of completed or ongoing investigations carried out by the Pacific Salmon Commission that are deemed of sufficient interest to be made available to the scientific community and the public.



Pacific Salmon Commission
600 - 1155 Robson Street
Vancouver, B.C.
V6E 1B5
(604) 684-8081

Pacific Salmon Commission
Technical Report No. 25

# An Action Plan in Response to Coded Wire Tag (CWT) Expert Panel Recommendations

March 2008

Correct citation for this publication:

Pacific Salmon Commission Coded Wire Tag Workgroup. 2008. An action plan in response to Coded Wire Tag (CWT) Expert Panel Recommendations. Pacific Salmon Comm. Tech. Rep. No. 25: 170 p.

# PACIFIC SALMON COMMISSION
# CWT WORKGROUP

# AN ACTION PLAN IN RESPONSE TO CWT EXPERT PANEL RECOMMENDATIONS

March 2008

## CWT Workgroup Members

Marianna Alexandersdottir (NWIFC, Chair)
Ethan Clemons (ODFW)
Carrie Cook-Tabor (USFWS)
Allen Grover (CDFG)
Annette Hoffmann (WDFW)
Ron Josephson (ADFG)
Scott McPherson (ADFG)
Mike Matylewich (CRITFC)
Gary Morishima (QIN)
George Nandor (PSMFC)
Chuck Parken (CDFO)
Patrick Pattillo (WDFW)
Brian Riddell (CDFO)
Norma Jean Sands (NMFS)

## ACRONYMS

| | |
|---|---|
| ADFG | Alaska Department of Fish and Game |
| ASFEC | Ad-Hoc Selective Fishery Evaluation Committee |
| AUC | Area Under the Curve |
| BC | British Columbia |
| CAS | Cohort Analysis System (CTC database) |
| CDFG | California Department of Fish and Game |
| CDFO | Canadian Department of Fisheries and Oceans |
| CRITFC | Columbia River Inter-Tribal Fisheries Commission |
| CTC | Chinook Technical Committee |
| CoTC | Coho Technical Committee |
| CWT | Coded Wire Tag |
| CNR | Chinook Non-Retention |
| DIT | Double Index Tagging |
| ETD | Electronic Tag Detection |
| ER | Exploitation Rate |
| ISBM | Individual Stock Based Management |
| MM | Mass Marking |
| MOU | Memorandum of Understanding |
| MR | Mark Recapture |
| MRP | Mark Recovery Program |
| MSE | Mean Standard Error |
| MSF | Mark Selective Fishery |
| MSM | Mixed Stock Model |
| MU | Management Unit |
| NSF | Non-Selective Fishery |
| NWIFC | Northwest Indian Fisheries Commission |
| ODFW | Oregon Department of Fish and Wildlife |
| PEF | Production Expansion Factor |
| PSC | Pacific Salmon Commission |
| PSE | Percent Standard Error |
| PSMFC | Pacific States Marine Fisheries Commission |
| PST | Pacific Salmon Treaty |
| QIN | Quinault Indian Nation |
| RMIS | Regional Mark Information System |
| RMPC | Regional Mark Processing Center |
| SEAK | Southeast Alaska |
| SFEC | Selective Fishery Evaluation Committee |
| SUS | Southern United States |
| TBR | Transboundary |
| TCDS | Technical Committee on Data Sharing |
| USFWS | United States Fish and Wildlife Service |
| WCVI | West Coast Vancouver Island |
| WDFW | Washington Department of Fish and Wildlife |

## ACKNOWLEDGEMENTS

The CWT Workgroup wishes to thank the following individuals who are not listed as workgroup members but who contributed knowledge, time and effort to this document. This includes Jim Longwill and Dan Webb of the PSMFC, Gayle Brown, Rick McNicol, Roberta Cook, Kathy Fraser, Brenda Ridgway of CDFO, Melodie Palmer-Zwahlen of CDFG and Charmane Ashbrook and Kirt Hughes of WDFW. We would also thank the PSC staff for their assistance in coordinating our meetings.

# Table of Contents

# List of Tables

# List of Figures

# Executive Summary

The Expert Panel stated in their report (Hankin et.al. 2005) that "…it will be important to maintain a reliable coded wire tag (CWT) system during the transition period to ensure data continuity and to allow evaluation of the relative performance of some new technology or approach as compared to the CWT system". The Pacific Salmon Commission (PSC) established a CWT Working Group to develop recommendations to correct deficiencies in data collection and reporting throughout the basic CWT system and to improve analysis of CWT recovery data.

The Working Group reviewed the past performance of the coastwide CWT program, assessed its current status, and developed guidelines to improve the statistical basis for the future program. While changes to fisheries, marine survival rates, and budget limitations have impacted the CWT program, this review indicates that an effective and efficient program can be restored with agreement on reasonable objectives for tagging, sampling, and data sharing criteria. There will, however, be limitations to the program when marine survival becomes very poor, excessive fishery stratification is done, and if mass marking and mark-selective fisheries significantly expand. Data systems can be developed to address most aspects of the latter, but with significantly increased costs.

The Working Group addressed the first four recommendations of the CWT Expert Panel Report (Hankin et al. 2005) and the associated questions provided by the PSC (Section 1.3). This report is structured in four primary chapters addressing the assignments, plus extensive appendices to support summary tables, recommendations, etc.:

- i) Chapter 4, Current Status of the CWT Program,
- ii) Chapter 5, Criteria for Precision and Accuracy,
- iii) Chapter 6, Decision Theoretic Model (an initial tool developed to set tagging and sampling targets), and
- iv) Chapter 7, Conclusions and Recommendations.

The question of the representativeness of indicator stocks (Recommendation 4 of the Expert Panel Report) was not fully addressed, but the geographic coverage of indicator stocks is included in the issues considered in the chapters above, and in Appendix D. Additional studies regarding this topic for Chinook salmon are being conducted in Alaska, Canada, the Columbia River, and Oregon.

The Work Group identified issues in three broad categories:

- a) limited tag recoveries in fisheries and spawning escapements, these observed tags are the fundamental basis for all applications of CWT data,
- b) inadequate attention to sources of bias, such as unsampled catches, voluntary recovery of tags in some recreational fisheries, inaccuracy in spawning estimation, and
- c) incomplete coverage of indicator stocks representing salmon production regions, particularly for coho salmon.

The Work Group did not focus on additional issues associated with mass-marking and mark-selective fisheries (MSF), but emphasize that any current proposal to assess MSFs assumes a sound technical basis in the CWT program.

The recent status of the CWT program with respect to precision of estimates is thoroughly assessed in Chapter 4 and summarized for the coast wide indicator stocks in Figure 4-2 (Chinook) and Figure 4-3 (Coho). These figures present matrices of stocks (Rows) and tagging and sampling issues (Columns) to encapsulate the program in two figures. Agencies provided greater details of recognized limitations to their CWT program in Appendix A and section 7.3. Figures 4-2 and 4-3 do not provide information on potential sources of bias in CWT-based estimates (e.g., absence of an indicator stock or a fishery that is not sampled), but these issues are included in Appendix A and section 7.3.

Each of the issues identified can be addressed by a program design based on observed tag recoveries (not fixed numbers of tags released), and with greater responsiveness to change (treat the program as dynamic not static), representative sampling of all components of a cohort (excluding natural mortality), and a focus on issues limiting the data quality of the program coastwide (yellow and red columns in Figures 4-2 and 4-3). To address these issues, the Work Group recommends the following guidelines for improving the statistical basis for estimates produced by the CWT program:

i) achieve ten (10) observed tags within each sampling stratum (defined by fishery or escapement location, time period, and age for Chinook salmon) to provide a 30% percent standard error (PSE) on estimated tags within strata[1] that represent an important proportion of the stocks total exploitation rate (at least 2.5%) or escapement rate (Section 5.3, Figure 5-1);
ii) establish tagging and sampling rates to achieve these targets in eight of ten brood years (to account for observed variation in marine survival), see Section 6.1;
iii) recognizing the variability in survival rates over time and between stocks, and for quality assurance, use a model such as the Sampling Guidelines Model presented in this report to establish tagging and sampling rates for annual programs (Figures 6-3 to 6-5, and Appendix C) to achieve the first guideline;
iv) minimize potential biases by representative sampling of all catches and spawning escapements and achieving minimum sampling targets per strata;
v) identify sources of harvest impacts that may go unreported; and
vi) establish quality control measures and periodic reviews of the program's performance against these new guidelines.

To address limitations recognized in Chapter 4 and Appendix A, implement these design guidelines, and acknowledge the specific differences between stocks (e.g., ranges of survival rates, migration patterns, and variation in fishery stratification), agencies will need to review their CWT programs. It is important to note that each agencies CWT programs are not conducted in isolation of other agencies. Costs for restoring elements of the CWT program were

[1] It is important to note that the PSE achieved will increase if the precision of a catch or escapement estimate is greater than zero (0). If the PSE for catch or escapement is greater than zero, then the PSE on the estimated numbers of tags within those strata can not be less than the PSE of the estimated catch or escapement.

included by some agencies in Appendix A, but the full costs of the revised program can not be established until the inter-agency needs are assessed.

Summary Recommendations (Section 7.5).

1. The Chinook Technical Committee (CTC) and Coho Technical Committee (CoTC) should review the indicator stocks for adequate coverage in representing natural stocks. The workgroup identified gaps in geographic and stock-type tag representation (Section 7.1 and 7.3) which should be addressed by the PSC and agencies. A greater commitment to establishment and maintenance of indicator stocks is required to fully utilize the capability of the CWT program to support fishery management actions affecting the Parties under the PST.

2. Agencies and/or the CTC and CoTC should evaluate all Chinook indicator stocks and all tagged groups from coho regional groupings for consistency with statistical guidelines described above. The workgroup recommends that particular attention be paid to the adequacy of CWT release sizes in light of trends and variability in survival rates and changes in fishery exploitation rates.

3. Agencies should evaluate their escapement estimation and sampling programs where tagged Chinook and coho groups are present on the spawning grounds. A review of the sampling programs (Tables 4.2 and 4.3) indicates that spawning ground sampling is often not in place or inadequate and that quantitative estimates of escapement need to be improved, particularly to limit uncertainty

4. Agencies should evaluate their sampling programs with respect to their ability to provide representative samples of all tagged fish (marked and unmarked) in fisheries and in the escapement (Section 7.1.4).

5. The Work Group recommends that the PSC request a written response from each agency involved in the coast wide CWT program by October 1, 2008 and have the PSC technical committees review the collective response.

6. The workgroup recommends that the development of a multi-stock, multi-fishery decision theoretic model be supported to assess the efficacy, efficiency, and interactions of agency investments to improve the CWT program (see Appendix C).

7. The CWT workgroup recommends that a workgroup including members of the CoTC, CTC, Data Sharing and Selective Fishery Evaluation Committee (SFEC) be created and charged with reviewing the current validation process for CWT data and provide recommendations for improvement (Section 7.2 and 7.4).

8. Agencies should evaluate their sampling programs to ensure that data required for estimating impacts of MM and MSF are properly reported. Mark selective fishing impacts both sampling and reporting programs. Specifically, reporting of sample method (electronic vs. visual), fishery type (selective vs. non selective), tag group type (double

index tagging (DIT) vs. non-DIT) and mark status in release and recovery file are new data fields and are not consistently reported. In addition, the reporting of the tag/mark status in the catch-sample file has become more complicated and agencies should review their procedures.

# 1 Introduction

The coded wire tag (CWT) was introduced in the 1960s and has provided unparalleled information about ocean distribution patterns and fishery impacts for Pacific salmon along the Pacific coast. For the last 30 years, CWT data has provided the fundamental basis for assessment and management of Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon. Prior to the advent of the CWT, large-scale troll and sport fisheries had developed in marine areas along the Pacific coast. Catches were sustained by large, but unknown, mixtures of hatchery and wild populations, the composition of which varied from year to year and area to area. Fishing mortality rates were unknown but the cumulative effect of fishery and other impacts were resulting in declining trends in spawning escapements for many natural populations. Fishery harvest rates (the proportion of fish available to a fishery that are killed by that fishery) could not be estimated or monitored, except for some fisheries in terminal areas. Competitive over-fishing and extensive debate amongst users and agencies was fueled by limited data and assessments. The ability to unambiguously identify specific groups of fish using CWTs provided the first opportunity to monitor and assess the harvest patterns and survival rates and a quantitative basis for development of management actions.

The CWT was originally developed for evaluation of individual release experiments carried out with hatchery fish (Jefferts et al. 1963). The CWT is a small piece of magnetized wire (usually 0.25 x 1.1 mm) which is implanted in the nasal cartilage of juvenile salmonids. Each piece of wire contains a code that uniquely identifies a group of fish. Because Pacific salmon are semelparous and have strong homing fidelity, adult fish escaping fisheries return to well-defined geographic areas, usually near their release site. Since CWTs are inserted into juvenile fish prior to ocean migration, the technology provides a means to track the fate of specific groups of salmon from release through to maturity (i.e., throughout their life cycle). Recovery of CWTs required an external mark since the tag was not visible externally. By agreement of management agencies in 1977, removal of the adipose fin (Ad) was sequestered (reserved) for fish that received a CWT (Ad+CWT). Fish could then be inspected visually for the presence of a tag and snouts removed from those with missing adipose fins. In the late 1970s, management agencies also agreed to institute catch sampling and reporting protocols to facilitate sharing of data on where and when tagged fish were recovered, as well as associated sampling information.

Through this coordinated, coast-wide system, CWT recovery data have enabled fishery scientists to determine exploitation patterns for individual groups of fish and have assisted decision-making required to conserve the resource. In the early 1980s, stock and fishery assessment methods based on CWT recovery data provided the means to estimate exploitation rates (ERs) for individual stocks. Cohort analysis methods (CTC 2001) applied to CWT recovery data permitted estimation of age and fishery-specific ERs, age-specific maturation rates, survival from release to age 2, and total mortality. These methods quantified and characterized the timing and location of fishery impacts for the entire migratory range and life cycle of individual stocks. Exploitation patterns of natural stocks were assumed to be the same as those determined for CWT release groups of hatchery fish that had similar brood stock origin, similar maturation schedule, and migration timing. The integration of CWT-based cohort analysis into fishery management models provided the means to assess how to constrain fishing mortality to levels

appropriate for the status and productivity of individual stocks. These models were instrumental in enabling the U.S. and Canada to reach agreement on a coast-wide Chinook rebuilding program, which became a cornerstone for the 1985 Pacific Salmon Treaty (PST).

For three decades, the CWT has provided a practical, efficient, and cost-effective means for stock- and fishery-specific assessment. Coordinated, coast-wide sampling and reporting systems facilitate sharing of information on CWT releases and recoveries, and standardized methods for CWT data analyses reduce opportunities for misinterpretation. The capacity to conveniently analyze experimental results for individual CWT release groups in a timely manner has proven invaluable for salmon fishery management, research, and monitoring. The Pacific Salmon Commission's (PSC) Ad-Hoc Selective Fisheries Evaluation Committee (ASFEC 1995) summarized the main reasons why all salmon fishery management agencies in the Pacific Northwest rely upon the CWT:

1. *the CWT program includes fully integrated tagging, sampling, and recovery operations along the entire west coast of North America;*
2. *the CWT provides sufficient resolution for stock-specific assessments; and*
3. *the CWT is the only stock identification technique for which a historical record (generally back to the mid 1970s) of stock-specific assessments may be computed.*

No other practical mark-recovery system has yet been devised that is capable of providing this level of detail in such a timely fashion.

The historic success of the CWT program has been in no small part due to the high level of coordination and cooperation among the coastal U.S. states and British Columbia and to the consistency of CWT tagging and recovery efforts across the many jurisdictions. Despite the emergence of other stock identification technologies, including various genetic methods and otolith thermal marking, the CWT recovery program remains the only method currently available for estimating and monitoring fishery impacts on individual stocks of coho and Chinook salmon when implementing fishing agreements under the PST (Hankin et al. 2005).

## *1.1 Chinook and Coho Salmon in the Pacific Salmon Treaty*

Chinook and coho are species of Pacific salmon. These species are anadromous and semelparous and exhibit a high degree of homing, leading to the development of populations that are relatively reproductively isolated and adapted to local environmental conditions.

Chinook are the largest and longest-lived species of Pacific salmon and tend to spawn in larger river systems. More than a thousand spawning populations (stocks) of this species are found in rivers along the eastern Pacific Ocean. Several distinct spawning populations - often characterized by river entry timing, e.g., spring, summer, fall, winter - defined by a combination of timing and physical location may be found in a single river system. The PSC fishery regimes for Chinook are directed at a subset of specific stocks (indicator stocks) originating from northern Oregon through Southeast Alaska. PSC fishery regimes for Chinook are designed to constrain fishery exploitation so as to achieve spawning escapement goals for individual stocks. Because individual stocks can migrate over thousands of miles and be impacted by fisheries over an extended period of time, PSC fishery regimes incorporate a complex set of elements, many of

which depend on CWT analyses of these indicator stocks. The Chinook Technical Committee (CTC) of the PSC is charged to conduct annual analyses of CWT data to assess annual exploitation patterns and rates, variation in marine survival, annual abundance forecasts, compliance with requirements of PSC fishery regimes, etc. CWT data are also employed in stock-recruitment analyses (catch for many natural populations is unknown, but the ER can be estimated from an associated CWT indicator stock) to estimate recruitment used to develop spawning escapement goals.

Coho salmon spawn in numerous small, even intermittent streams. Several thousand populations of this species exist along the eastern Pacific Ocean. This species is characterized by an extended period of freshwater rearing (1 to 2 years) followed by approximately 18 months of rearing in marine areas prior to returning to the rivers to spawn. Coho tend to be distributed over a much smaller range in the ocean than Chinook, but their marine distribution appears to be much more variable than Chinook. PSC fishery regimes for coho are designed to constrain fishery exploitation on specified regional aggregates of stocks or management units (MUs) of naturally spawning coho, based on categorical conservation status (abundant, moderate, low). Under the PSC coho agreement, each party is required to constrain its fisheries so that cumulative ERs do not exceed negotiated limits. The Coho Technical Committee (CoTC) analyzes CWT recovery data using cohort analysis methods to provide historical perspectives on exploitation patterns and inform decision makers about the magnitude of fishery impact reductions required to meet target ER constraints. The annual estimation of ERs for CWT indicator stocks (for specific MUs) is used to estimate spawning escapements, stock compositions, and monitor compliance.

## *1.2 Emerging Problems with the CWT Program*

Under conditions of changing fisheries, tagging levels, and desired level of stratification, there has been increased concern regarding the quality of CWT recovery data and inferences that have been drawn from analyses of these data. The recent Report of the Expert Panel on the Future of the CWT Recovery Program for Pacific Salmon (Hankin et al. 2005) provided an extensive discussion of the emerging issues that are only summarized here:

1) In the early 1990s, survival rates for many natural stocks declined precipitously and managers responded by reducing fishery impacts to try to maintain spawning escapement levels. As survivals plummeted and fishery impacts decreased, fewer CWTs were recovered, thereby increasing statistical uncertainty with CWT-based estimates and further reducing the reliability of inferences drawn.

2) Statistical uncertainty surrounding CWT-based estimates has been the subject of increasing scrutiny. There are various sources of uncertainty surrounding CWT-based estimates and their application in salmon management processes. Statisticians recognize two components of uncertainty in estimating population statistics: variance and bias. Variance measures the variation associated with sampling and estimation procedures; this can generally be calculated. Bias measures the difference between the expected (or average) value of estimates and the true but unknown quantity being estimated (e.g., total fishery-related mortalities). The magnitude of bias is extremely difficult or impossible to determine. For example, catch-and-release mortality rates for sublegal-sized (shaker) salmon are

commonly applied as fixed values to the number of shakers released, but the true rates likely vary with size of fish released, gear, and fishery. These inherent statistical uncertainties were exacerbated by a convergence of other factors.

a) Budget pressures within agencies that have resulted in reduced sampling in various fisheries have also decreased the reliability of CWT recovery data and also introduced unknown bias.

b) An increase in the proportion of the total catch in recreational fisheries has also increased uncertainty in CWT-based estimates, because recreational catch is estimated and these fisheries frequently have lower sampling rates for tags. In general, the larger the proportion of total catch taken in recreational fisheries, the larger the uncertainty in CWT-based estimates.

c) Managers have also in recent years relied increasingly on alternative fishery management measures such as catch-and-release or species-selective fisheries. These non-landed mortalities are unsampled and now account for a much greater proportion of total fishery mortalities in the Southern U.S. jurisdiction.

3) A key assumption underlying PSC regimes is that the selected hatchery indicator stocks are representative of their associated natural stocks. Because of the difficulty of tagging and recovering sufficient numbers of naturally produced fish, direct validation of this assumption through CWT methods can be difficult and costly.

4) The PSC and fishery managers in general have requested estimates be provided at finer scales of fishery-time/area resolution to address management concerns. However, as strata become more refined (i.e., smaller), the uncertainty surrounding estimates of these individual ERs will increase (see page 8, Hankin et al. 2005).

## *1.3 The Current Assignment*

The PSC appointed the CWT Workgroup to identify tasks that would address the CWT-related recommendations of the Expert Panel (Hankin et al. 2005). The highest priority was to be placed on those tasks that need immediate action. Accordingly, the initial emphasis was to identify options to address current deficiencies in the CWT program (Expert Panel Recommendations #1-4). The recommendations below are quoted (in italics) from the Expert Panel report presented to the PSC (Hankin et al. 2005); the identified Workgroup tasks and the sections of this report that address the tasks are also presented.

**RECOMMENDATION 1** – *Substantial improvements must be made in the CWT system to insure that the quality and reliability of collected data are consistent with the increasing demands being placed on these data by fishery managers. Areas requiring attention include quality control/quality assurance, and various sampling design issues including expansion of catch and escapement sampling in areas where little or no sampling currently takes place.*

Tasks

1) Develop a matrix outlining where quality control/quality assurance issues are occurring within the current CWT system and identify options and associated costs for corrective measures - Chapter 7 and Appendix A.
2) Identify the current tagging levels for indicator stocks utilized by PSC technical committees - Chapter 4.
3) Identify the current sampling rates occurring for marine fisheries, freshwater fisheries, spawning grounds and hatchery returns. Where the recommended or targeted sampling rates are not being achieved, identify options and costs for corrective measures - Chapter 4, 7 and Appendix A.
4) Develop recommendations for sampling design protocols for catch and escapement estimation and sampling - Chapter 0.

**RECOMMENDATION 2** – *Explicit criteria should be developed for the precision of statistics to be estimated from CWT recovery data. New guidelines for CWT release group sizes and fishery and escapement sampling rates should be based on these explicit criteria.*

Tasks

1) Describe the precision currently achievable for estimated parameters derived from the current CWT data, where the status quo is defined as the precision level given that current sample design targets are being met in all areas (e.g., tagging levels, coverage and sampling rates) – Chapter 5.
2) Provide options for modifying current CWT release group sizes and sampling rates for fishery and escapement that provide increments of improved precision over status quo – Chapter 0.

**RECOMMENDATION 3** – *We recommend that the utility of a decision-theoretic approach, intergrading cost, benefits, and risk into a formal evaluation structure be investigated as a means of prioritizing potential improvements (e.g., measures to improve CWT data – reporting, sample design, and protocol) to the CWT system. The approach should identify the release group sizes and recovery programs required to meet the statistical criteria for CWT recovery data. Sampling programs should include all fisheries, hatcheries, and spawning ground areas where CWT ER indicator stocks are present.*

Task

1) Work with the relevant agencies to identify cost considerations for the actions associated with the first three recommendations – Chapter 0 and 7.

**RECOMMENDATION 4** – *We recommend completion of a comprehensive survey and statistical analysis of all relevant published and unpublished CWT studies that concerns the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts. This review should also include new analysis of relevant agency-collected data that have not yet been previously subject to analysis. Recommendations for additional studies should be made if they are judged necessary.*

Tasks

1) Summarize the results from all the relevant management agencies' published and unpublished CWT studies that concern the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts – Appendix D.
2) Review current indicator stock coverage and provide recommendations where additional analysis could be conducted for peer review that would advance understanding of the relationship between hatchery indicator stocks and their natural counterparts – Appendix D.

# 2 Primary Uses of CWTs by the CTC and CoTC

The PST specified that the parties maintain an ER stock program to provide the Chinook and Coho technical committees with information from each production area for the annual evaluation of fisheries and to forecast future harvest impacts. The intent was to utilize these indicator stocks to monitor and evaluate the effectiveness of the management measures agreed to by the PSC. The indicator stock programs provide information needed for cohort and ER analyses for wild and hatchery coho and Chinook salmon.

The CWT database has a variety of uses outside of those of the CTC and CoTC, including regional management as well as hatchery evaluation and monitoring. This report focuses on the use of CWTs by these PSC committees.

## *2.1 Indicator Stocks Used by the CTC and CoTC*

The basic statistic used by PSC technical committees and managers for evaluating fisheries is the ER estimated by fishery for groups of Chinook and coho salmon. In 1985, the CTC and CoTC initiated the use indicator stock programs. Stocks were selected that were 1) coded-wire-tagged and available in sufficient years and 2) representative of particular basins, MUs, or regions of production. Exploitation Rate Indicator (ERI) stocks were to be chosen based on the following guidelines (Morishima 1986):

1) In aggregate, their ability to represent all major regions and racial types of interest to the PSC;
2) The stock must be sufficiently abundant and easily tagged so that the agency responsible can make a long-term commitment for tagging the stock;
3) The agency responsible for tagging the stock must make a commitment to sample and estimate the escapement of tagged fish and report the results to the PSMFC in a timely manner.
4) Reliable estimates of catch and escapement must be available.

The intent was to utilize indicator stocks to monitor and evaluate the effectiveness of the management measures prescribed by the PSC. Additional CWT groups are used to describe fish distribution among fisheries and estimate ERs for other stocks. The CoTC is currently using such groups to develop a management model for coho salmon (see Appendix D).

<u>Chinook.</u> The CTC relies upon a set of CWT indicator stocks to monitor the effects of PSC fishery regimes through an annual ER analysis. Statistics derived from cohort analysis on indicator stocks provide a time series of changes in fishery harvest rates, brood year ERs, maturation rates, fishing mortality rates and distributions, and pre-recruitment survival.

<u>Coho</u>. No formal, coastwide indicator stock program presently exists for coho. The analyses performed by the CoTC have been opportunistic: specifically, they have been forced to rely on the use of available CWT release and recovery data. These CWT groups were released for various purposes and sometimes employ brood stocks of uncertain origin. Further, while current PSC regimes for southern coho are based on constraining ERs on natural MUs, the ability to

monitor implementation of the PSC agreement addressing coho salmon is limited by the lack of a set of corresponding indicator stocks.

## *2.2 Uses of CWTs by CTC and CoTC*

This section briefly describes the major uses of CWT data by the PSC technical committees.

### 2.2.1 Representation in Regional Planning Models

Regional planning models for Chinook and Southern Coho depend critically on CWT release and recovery data to represent the distribution and exploitation patterns of tagged fish groups representative of individual MUs.

### 2.2.2 Variability in Distribution and Exploitation Patterns

CWT recovery data are employed to evaluate inter-annual variability in harvest distribution patterns and exploitation of individual stocks.

### 2.2.3 Abundance Forecasting

Annual estimates of marine survival generated from CWT release and recovery data, along with other data such as terminal run size, provide the basis for estimates of survival trends and development of long-term datasets, both of which are used directly and indirectly for forecasting pre-fishery cohort abundance and terminal runs.

### 2.2.4 Estimating Stock Productivity

Cohort reconstructions are based on CWT data that are applied to natural escapement abundance to estimate production resulting from parent spawning escapements. These data and estimates of pre-recruitment survivals provide the basis for stock-recruitment analysis and the estimation of stock productivity and capacity to sustain harvest. The PSC Coho and Chinook Agreements are based on constraining fishery exploitation to levels appropriate to conserve natural stocks and produce maximum sustainable harvest.

### 2.2.5 Monitoring and Post-Season Review of Management Regimes

The CTC and CoTC are responsible for annually reporting estimates of fishery ERs on natural stock groups by specific groups of fisheries. For Chinook, fishery harvest rate indices and individual stock based management (ISBM) indices derived from cohort analyses are reported annually to the PSC and used in annual calibrations of the PSC Chinook Model. For coho, the ERs experienced are compared against limits established by the 2002 PSC Coho Agreement.

### 2.2.6 Other

Long-Term Data Set for Basic Biological Assessments. The CWT database is critical to the ability of the CTC and CoTC to increase understanding of how salmon respond to variable ocean conditions. Currently, the CWT system provides the only long-term source of data available to monitor survival, distribution, and exploitation patterns.

Stray Rates. Recoveries of tags on spawning grounds, hatchery rack(s), and extreme terminal fisheries outside of the geographic origin of the CWT release provides quantitative and/or qualitative information on stray rates.

Size at Recovery in Fisheries. Data associated with CWT recoveries (date, time, location, gear, etc.) are useful for examination of inter-annual and inter-population differences in size/growth rates. These data help identify issues or interpret observed trends in fishery impacts (e.g., long-term changes in average fish size). Size at age data help to directly model the effects of changes in minimum size limits in proposed fishing regulations. Additionally, for some stocks these data are used as indicators of condition for abundance forecasting (e.g., impacts of El Nino events) or survival.

Estimation of Regional Coho Production. The CoTC relies on CWT recovery data to produce estimates of total abundance for coho production units coastwide. This is accomplished through the use of CWT recovery data in run reconstruction and estimation of production expansion factors (PEF) in the mixed-stock model (MSM). PEFs are estimates of how many fish a single CWT represents from a given MU.

Estimation of Escapement of Natural Stocks. Estimates of the numbers of coho escaping fisheries to spawn are not available for some coho production units. The CoTC generates estimates of escapements based on estimates of fishery contributions of a coho production unit and estimates of ERs of selected hatchery indicator stocks.

# 3 Key Elements of the CWT program

The CWT program consists of several key components involving tagging, recovery, and data reporting. These components are coordinated and implemented coastwide to provide statistically reliable data for stock assessments and fishery evaluations (TCDS 1989; Johnson 2004) (Figure 3-1). A regional mark committee coordinated through the PSMFC and the PSC Data Sharing Committee ensure that unique codes are employed for tagging and that inter jurisdictional implications of marking programs are considered. CWTs are recovered by programs intended to sample a minimum proportion of fishery catches and escapements. Agencies use standardized formats and protocols to report release and recovery data to centralized locations where data are validated and stored for access.

The components of the CWT data systems are illustrated in Figure 3-1. Figure 3-2 illustrates the main components of the data exchange protocols between the Canadian and U.S. data systems.

## *3.1 Quality Assurance and Control*

The parties to the PST have agreed to maintain the tagging and recovery program designed to provide statistically reliable data for stock assessments and fishery evaluations. The CWT system consists of several elements:

(1) There are separate U.S. and Canadian CWT reporting databases. The U.S. system (Regional Mark Information System, RMIS) is maintained by the Regional Mark Processing Center (RMPC) of the Pacific States Marine Fishery Commission (PSMFC). The Canadian system (Mark Recovery Program, MRP) is maintained by the Canadian Department of Fisheries and Oceans (CDFO).
(2) Both countries acquire CWT data that originates within their country and provide access to information contained in their databases in a manner that satisfies users of their country.
(3) Reporting requirements and centralized responsibilities for data exchange between Canada and the United States are standardized to ensure both databases are identical.
(4) Cooperative development of standardized formats for reporting release, recovery, and catch sample data has been employed. The release system provides information on all releases coastwide, tagged and untagged. The recovery system encompasses the sampling and recovery information for all fisheries and escapement locations coastwide.
(5) There are inter-agency processes for review, coordination, and modification of CWT data.
(6) There are rules for data validation and procedures for correction.

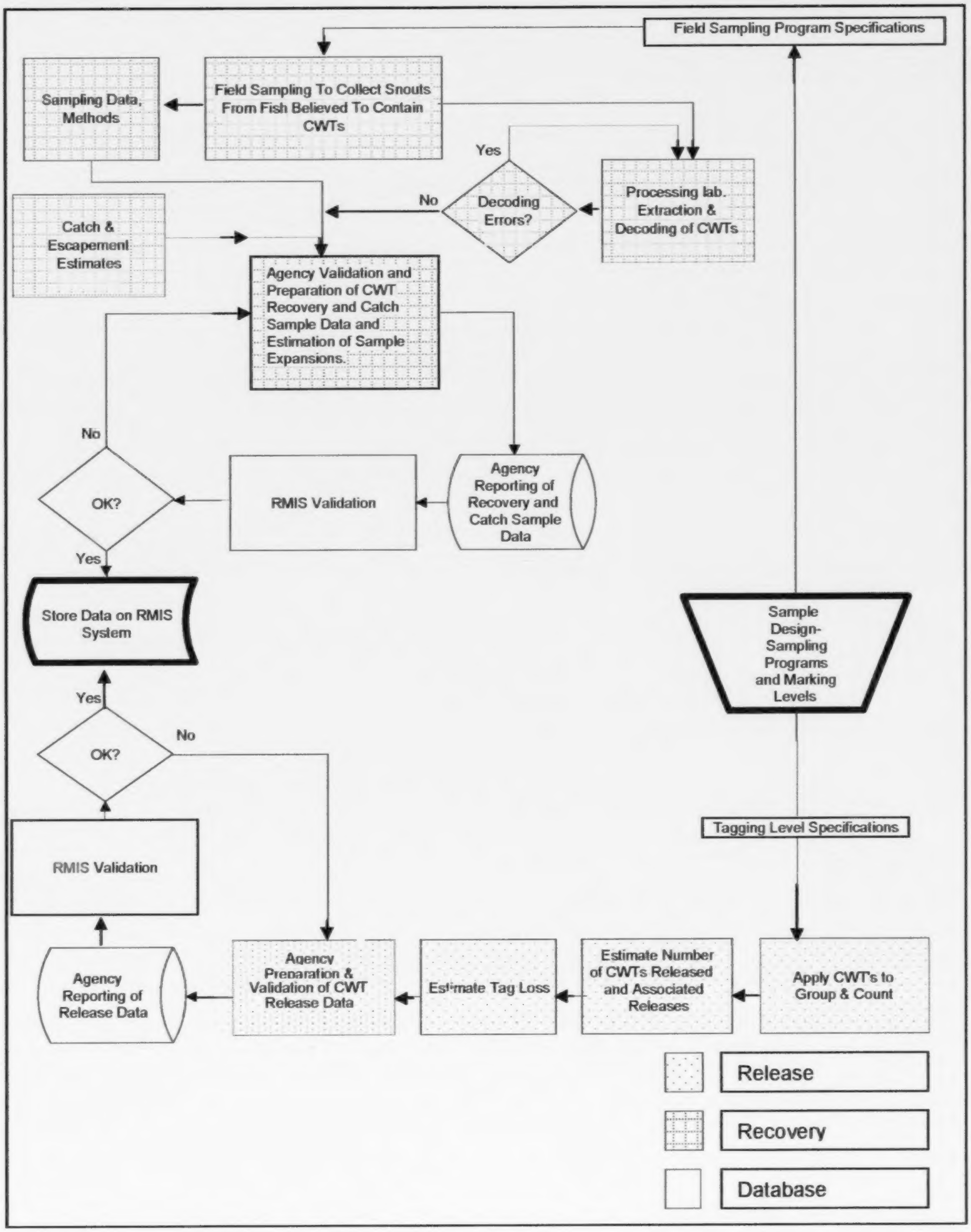


Figure 3-1. The sequence of data handling and management procedures of the CWT program, focusing on tag release, recovery, and reporting.

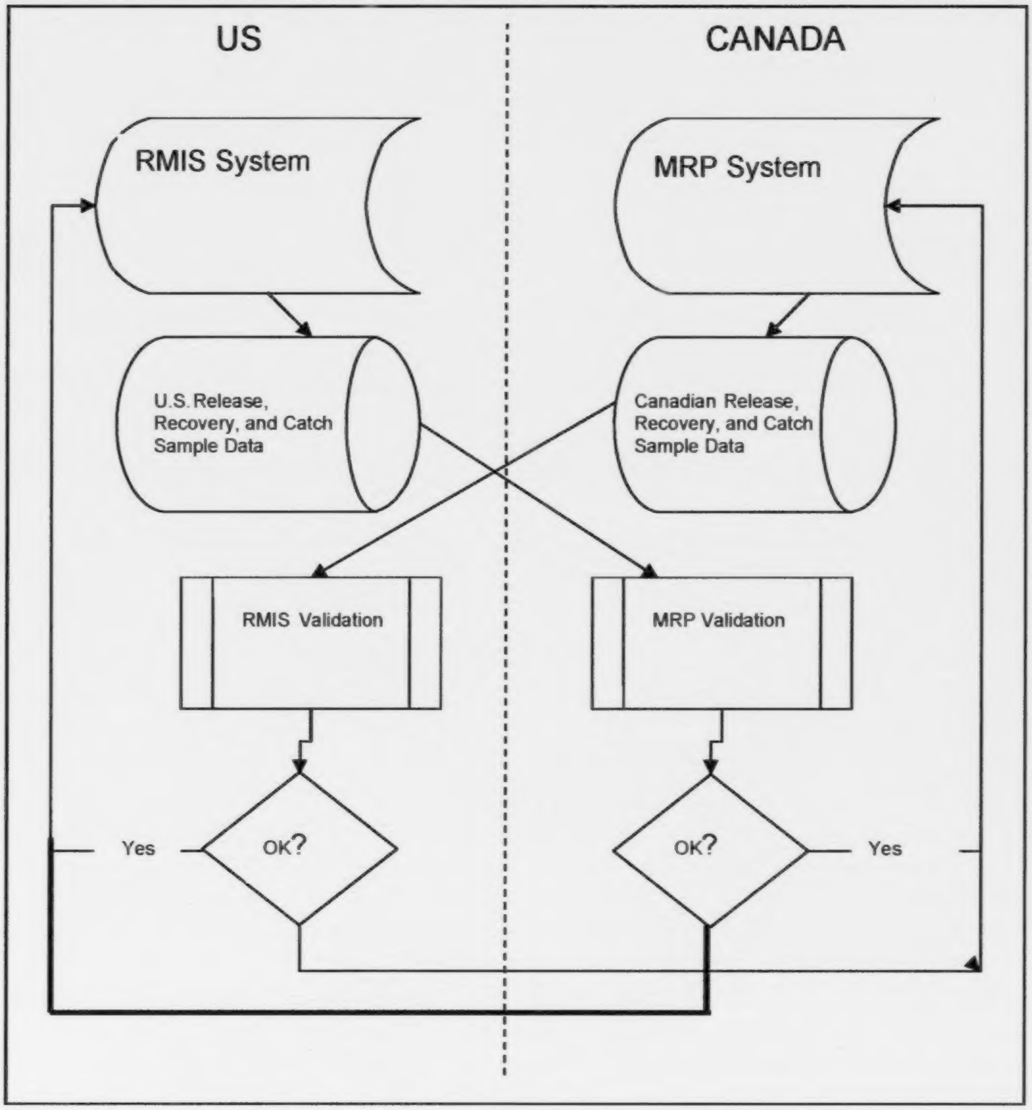


Figure 3-2. The main components of the data exchange protocols between the Canadian and U.S. CWT database systems.

### 3.1.1 Tagging Programs

Chinook and coho salmon tagging programs are carried out by agencies coastwide. The tag groups are specific releases of hatchery juveniles and wild or naturally-produced juveniles. For CWT analyses, tag codes must be unique for each tag group. The data reported with each CWT release group provides information on 1) the origin and release location of the fish and 2) the age of the fish in the tag group. The following conditions are necessary for survival rate and ER analyses using CWTs:

- Sufficient tags are released to allow estimation of statistics with the desired level of precision. For the purposes of using tag groups as indicator stocks (CTC) or regional representatives (CoTC), tagging level criteria are currently set at 200,000 for Chinook salmon and 45,000-75,000 for coho salmon.[2]
- Tag loss and tag mortalities are estimated within defined limits of uncertainty.
- Number of tagged fish released is known or if there is a need to estimate pre-recruitment survival then it should be known with little or no error.
- Total numbers of fish that are represented by a hatchery CWT release group is known without error, which is required if there is a need to estimate contribution of hatchery production.

An adequate time series of data must be acquired to use CWT data to monitor changes in productivity, survival, and exploitation patterns over time.

### 3.1.2 Sampling Program

Coast wide sampling programs that recover CWTs in commercial and recreational fisheries, in hatcheries, and on spawning grounds have been in place for three decades. Reported tag recoveries from returning adult fish are on the order of 300,000 per year. Quality control is the responsibility of the agencies conducting the tagging and sampling tasks and reporting the results.

CWT sampling is stratified to achieve management and statistical goals. For example, fisheries are sampled by area and gear and period, where period can be week, bi-weekly, month, season, or year. The definition of the spatial-gear-time strata for sampling is determined by the conduct of the fisheries and the preferences of the sampling agency. Estimation of tagged fish harvested or in escapement in a sample stratum depends on some basic assumptions, including the following:

- Sampling in each stratum is representative. Representative indicates that either sampling is random, i.e., all members of the population being sampled have equal chance of being sampled or that there is no difference between the segments of the population that are

[2] These "standards" were established in the late 1970s and early 1980s for the purpose of providing estimates of brood year ERs with acceptable levels of precision. The 200,000 CWT release group size for Chinook was established for fall Chinook fingerling releases, based on average estimated survival, fishery patterns, and brood year ERs during that period.

available for sampling and the segment that cannot be sampled. Fisheries or spawning populations cannot be randomly sampled according to the definition above, therefore sample strata should be structured to include fishery or spawning areas and periods that are similar in the stock composition of the populations present. Under this assumption estimates of the number of tagged fish harvested or in escapement in the strata are unbiased for each tag code.

- The total harvest or escapement is known or estimated without bias for the purposes of calculating a sample expansion to expand the observed tagged fish to total tagged fish harvested or in the escapement.
- All tagged fish in the sample are identified, collected, and processed.
- The sample rate is sufficient to provide an adequate number of tag recoveries to meet statistical criteria to estimate fishery and stock parameters. Currently there is a general criterion that all fisheries be sampled at 20%. Hatcheries are generally sampled at high rates, up to 100%, and spawning locations are sampled at levels ranging up to 50%, depending on the watershed and environmental conditions in each year.

### 3.1.3 Total Coverage of Fisheries and Escapement

An additional assumption required to estimate ERs is that all fisheries and escapement locations where a tagged stock is present will be sampled for tagged fish. This assumption of total coverage is necessary to provide unbiased estimates of cohort size and ER. It is the responsibility of each agency to sample all fisheries and escapement locations within its jurisdiction where tagged fish are present. Incomplete coverage of escapement locations results in underestimated cohort size, missing information, and estimates of ERs that are biased high.

### 3.1.4 Estimates of Total Catches and Escapement in Strata

In order to estimate the total number of tagged fish in harvest or escapement, the sampled tags are expanded for the fraction sampled by strata (area, gear, and period) (see Chapter 5). The sample fraction is the number sampled over the total available for sample, i.e., the total catch or escapement. In order for estimates of tagged harvest and escapement to be unbiased, the estimate of the total must be unbiased. In addition, it is necessary to provide estimates of total catch or escapement with sufficient precision to allow estimation of parameters within statistical criteria. The total catch (or escapement) and sample used for estimation of the sample fraction and tag expansion is reported to the RMIS or MRP catch-sample file.

### 3.1.5 Reporting and Validation

Release and sampling agencies have the responsibility of reporting release, catch-sample, and tag recovery data to the regional exchange points within the U.S. and Canada. Canada maintains its CWT database at the Pacific Biological Station and the U.S. at the PSMFC (Figure 3-2). Both databases are subjected to agreed upon validation rules for the data. The PSMFC provides programs for validating the data reported, and reports to submitting agencies when validation is not met. The validation rules are specified in the PSC Data Standards Workgroup (DSWG) database specification report (DSWG 2005) which may be found on the PSMFC web site. Validation rules indicate when columns must contain one of a set of allowed codes, such as for fishery type, gear type, species, agency code, or tag status. In addition, tag codes reported in a recovery file must match a tag code reported in a release file in the database. Information

regarding species, sampling periods, and other data items in a catch/sample file must match the corresponding information in the recovery file. The location codes (for releases, recoveries and sampling sites) must follow certain rules such that the database operations can sort data by location. These are just some of the validation rules used. All reporting agencies are responsible for ensuring that complete and accurate data are reported.

# 4 Current Status of CWT Program

Quality assurance encompasses all activities necessary to provide confidence that a monitoring program will meet its stated objective(s). For the CWT system, this includes sample design (tagged groups and tagging levels, fishery and escapement sample strata, and sampling rates) and statistical criteria (precision and accuracy) for specific statistics estimated from CWT data. Quality control pertains to the measures necessary to ensure that the CWT data are accurately and timely reported (e.g., sampling methods, reporting, and validation). This includes methods for tagging fish, release methods of tagged groups, methods of sampling in fisheries and in hatcheries and in escapement (e.g., are visual or electronic methods used, are all fish equally likely to be sampled, and are samples processed from all fish with tags detected?).

## *4.1 Summary of Tagging and Sample Rates for Chinook and Coho CWT Groups*

Two of the tasks set for the workgroup under Expert Panel Recommendation 1 were to identify current indicator stock tagging and sampling levels and consistency with current target levels. The current standard for fishery CWT sampling is 20% of the catch per strata, which is the goal for all agencies sampling commercial and sport fisheries. The workgroup summarized the catch-sample data available from the PSMFC RMIS indicating the proportion of reported sample strata with sample rates under 20% or not sampled at all (Table 4-1). These statistics were averaged over fishery years 2000-2004, separately for Chinook and coho and included average annual sample rates and total catch by fishery.

The PSC technical committees rely upon selected groups of CWT'd hatchery and wild Chinook and coho as surrogates to estimate impacts on natural stocks. For Chinook salmon the CTC uses a set of indicator stocks, which have been consistently tagged over long time series, and which have a standard target tagging level of approximately 200K per year. No formal system of indicator stocks has been established by the CoTC, although for Puget Sound and Washington coastal stocks tagging group standards are set at 40K and 75K, respectively. The CoTC uses any tagged coho released within a production region that meets specified criteria in procedures to generate contribution estimates for natural production from geographic regions. Table 4-2 and Table 4-3 summarize the number of tagged fish released, the average number of tagged fish returning to escapement, and sample rates at hatcheries and spawning grounds for each of the tagged stocks of Chinook and coho salmon used by the PSC technical committees.

Analyses of CWT data provide estimates of fishery ERs and other statistics employed for stock/fishery assessments and planning (see Chapter 2 for descriptions on the uses of CWT data by the CTC and CoTC). Recoveries of tagged fish in fisheries and escapement provide the basic input in these analyses. Table 4-4 and Table 4-5 show the distribution of these tagged stocks in fisheries averaged over brood years 1995-1999 (all ages combined). The fisheries included in these tables are those used by the CTC for ER analysis.

Table 4-1. Sampling statistics for fisheries that catch Chinook and coho salmon, averaged over the last 5 years (2000-2004) with comments as to the major issues for each fishery. Data are taken from RMIS catch-sample file, where a stratum is an area/period/gear and species record as reported by agencies. For both species, the table shows % of the annual fishery catch in total samples with all sample strata combined and the average annual catch; percent of all catch-sample strata reported to the PSMFC RMIS that are either sampled below 20% or not at all; and associated % of total annual catch represented by the under or un-sampled strata. NA identifies fisheries with small catches (e.g. less than a few hundred fish per year) and ND indicated no data were available. Key for comments is shown at bottom of table.

| | | CHINOOK | | | | | | COHO | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | Comments, see Key at Bottom of Table | |
| REGION | FISHERY | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | Chinook | Coho |
| SEAK | Traditional Troll | 34 | 222,837 | 8 | 3 | 1 | <1 | 32 | 1,480,228 | 2 | 1 | 4 | 1 | | |
| | Experimental Area Troll | 47 | 35,486 | 7 | 13 | 17 | 2 | 35 | 2,284 | 9 | 7 | 42 | 32 | | |
| | Traditional Purse Seine | 16 | 13,332 | 18 | 81 | 30 | 7 | 14 | 382,240 | 46 | 68 | 23 | 6 | 1 | 1 |
| | Traditional Drift Gillnet | 25 | 6,705 | 23 | 51 | 23 | 7 | 25 | 308,697 | 30 | 37 | 8 | 1 | | |
| | Traditional Set Net | 4 | 2,835 | 3 | 4 | 92 | 85 | 1 | 169,668 | 3 | 11 | 97 | 89 | | |
| | Sport | 19 | 72,375 | 58 | 68 | 3 | 2 | 25 | 171,047 | 29 | 33 | 7 | 6 | 1 | |
| | Terminal Purse Seine | 12 | 12,892 | 20 | 66 | 51 | 22 | 4 | 24,035 | 16 | 54 | 68 | 43 | 1,3 | 1,3 |
| | Terminal Area Drift Gillnet | 2 | 6,680 | 3 | 6 | 93 | 91 | 3 | 21,039 | 2 | 18 | 94 | 75 | 1,3 | 1,3 |
| | Terminal Troll | 12 | 5,307 | 19 | 44 | 65 | 37 | 19 | 2,256 | 2 | 6 | 88 | 62 | 1,3 | 1,3 |
| | MIC Drift Gillnet | 30 | 1,898 | 28 | 28 | 15 | <1 | 17 | 33,843 | 41 | 67 | 3 | 5 | | |
| | MIC Purse Seine | 2 | 777 | 23 | 70 | 74 | 30 | 5 | 7,988 | 36 | 48 | 56 | 45 | 1 | 1 |
| British Columbia | Georgia Strait Troll | 15 | 372 | 15 | 33 | 67 | 37 | NA | NA | NA | NA | NA | NA | 3 | 3,6 |
| | North Central Troll | NA | NA | NA | NA | NA | NA | 12 | 12,001 | 19 | 28 | 56 | 35 | 3 | |
| | North Troll | 30 | 85,377 | 21 | 39 | 55 | 1 | 24 | 101,244 | 14 | 56 | 57 | <1 | 3 | 1,3 |
| | NW Vancouver Island Troll | 24 | 44,504 | 15 | 50 | 75 | 11 | NA | NA | NA | NA | NA | NA | 3 | 3 |
| | South Central Troll | 5 | 333 | 15 | 45 | 80 | 54 | NA | NA | NA | NA | NA | NA | 3 | |
| | SW Vancouver Island Troll | 33 | 67,026 | 9 | 21 | 46 | 1 | NA | NA | NA | NA | NA | NA | 1,3 | |

| REGION | FISHERY | CHINOOK | | | | | | COHO | | | | | | Comments, see Key at Bottom of Table | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | | |
| | | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | Chinook | Coho |
| | Central Net | 35 | 4,270 | 23 | 27 | 23 | 14 | 15 | 11,296 | 7 | 4 | 68 | 77 | | 6 |
| | Fraser Gill Net | 51 | 8,248 | 3 | 12 | 19 | 6 | 29 | 81 | 6 | 12 | 55 | 63 | | |
| | Johnstone Strait Net | 33 | 383 | 6 | 20 | 60 | 27 | 212 | 193 | 0 | 0 | 71 | 71 | | 6 |
| | North Net | 42 | 14,771 | 9 | 7 | 16 | <1 | 30 | 7,286 | 8 | 67 | 66 | 5 | | 6 |
| | NW Vancouver Island Net | 12 | 2,371 | 0 | 0 | 78 | 58 | 8 | 969 | 10 | 9 | 55 | 73 | | |
| | SW Vancouver Island Net | 33 | 2,492 | 11 | 15 | 69 | 4 | 19 | 1,293 | 6 | 31 | 87 | 21 | | |
| | Fraser Indian Food Fishery | 0 | 24,971 | 0 | 0 | 100 | 100 | 0 | 1,511 | 0 | 0 | 100 | 100 | 1,2 | 1,2 |
| | Nuu-chah-nulth Abor. Fishery | 28 | 5,379 | 33 | 41 | 0 | 0 | NA | NA | NA | NA | NA | NA | 1 | 7 |
| | Alberni Canal Sport | 0[5] | 7,173 | 0 | 0 | 100 | 100 | 0[5] | 5,158 | 0 | 0 | 100 | 100 | 1,3,5 | 1,5 |
| | CBC Sport | 0[5] | 7,357 | 0 | 0 | 100 | 100 | 0[5] | 1,884 | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,5,6 |
| | Freshwater Sport | 0[5] | 22,146 | 0 | 0 | 100 | 100 | 0[5] | NA | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,5,6 |
| | GS Sport North | 0[5] | 21,348 | 0 | 0 | 100 | 100 | 0[5] | 3,281 | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,5,6 |
| | GS Sport South | 0[5] | 6,663 | 0 | 0 | 100 | 100 | 0[5] | 3,370 | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,5,6 |
| | Juan de Fuca Sport | 0[5] | 25,004 | 0 | 0 | 100 | 100 | 0[5] | 6,017 | 0 | 0 | 100 | 100 | 1,3,5 | 1,5 |
| | NBC Sport | 0[5] | 53,448 | 0 | 0 | 100 | 100 | 0[5] | 38,268 | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,5,6 |
| | WCVI Sport | 0[5] | 70,002 | 0 | 0 | 100 | 100 | 0[5] | 32,135 | 0 | 0 | 100 | 100 | 1,3,5,6 | 1,3,6 |
| Washington | Puget Sound Net | 23 | 6,242 | 8 | 23 | 53 | 20 | 21 | 78,646 | 15 | 43 | 42 | 7 | 6 | 6 |
| | Coastal Net | 26 | 6,276 | 10 | 22 | 43 | 4 | 34 | 35,548 | 16 | 21 | 17 | 2 | | |
| | Freshwater Net | 31 | 15,193 | 9 | 8 | 25 | 6 | 25 | 106,658 | 12 | 13 | 23 | 6 | | |
| | Ocean Troll | 41 | 56,766 | 15 | 20 | 32 | 9 | 24 | 31,110 | 18 | 31 | 47 | 12 | | |
| | Col R. sport (exc. B10) | 17 | 13,386 | 26 | 37 | 59 | 20 | 5 | 4,288 | 28 | 59 | 43 | 41 | | 1,3 |
| | Puget Sound Sport | 22 | 6,452 | 53 | 59 | 17 | 1 | 28 | 13,126 | 43 | 26 | 25 | 1 | 1 | 1 |

| REGION | FISHERY | CHINOOK | | | | | | COHO | | | | | | Comments, see Key at Bottom of Table | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | All Areas and Periods Combined | | Strata Sampled at >0 and <20% | | Strata Unsampled | | | |
| | | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | % Annual Catch in Total Sample | Average Annual Catch | % of Strata | % of Catch in those Strata | % of Strata | % of Catch in those Strata | Chinook | Coho |
| | WA Ocean Sport | 42 | 22,792 | 2 | 1 | 3 | <1 | 44 | 49,388 | 2 | <1 | 4 | <1 | | |
| | Col R Buoy 10 | 26 | 6,336 | 8 | 19 | 3 | <1 | 28 | 23,846 | 11 | 67 | 2 | <0 | | |
| | Freshwater Sport | 6 | 3,205 | 11 | 34 | 64 | 72 | 3 | 18,621 | 1 | 19 | 37 | 85 | 1,3,6 | 1,3,6, |
| Oregon | Ocean Troll | 31 | 182,838 | 22 | 39 | | 4 | | 3,896 | 9 | 24 | | 4 | 7 | 7 |
| | Ocean Sport | 40 | 17,133 | 3 | 4 | | 0 | | 25,554 | 2 | 4 | | 0 | 7 | 7 |
| | Columbia R Net | 45 | 87,231 | 5 | 22 | | 0 | | 97,219 | 6 | 2 | | 1 | 7 | 7 |
| | Columbia R Sport | 24 | 26,212 | 29 | 60 | | 0 | | 2,273 | 28 | 85 | | 0 | 7 | 7 |
| | Columbia R B10 Sp | 47 | 3,826 | 0 | 0 | | 0 | | 10,634 | 2 | <1 | | 0 | 7 | 7 |
| | Est fresh sport (non Col R.) | 34 | 4,371 | 12 | 21 | | 0 | | 96 | 0 | - | | 1 | 7 | 7 |
| California | Ocean Troll | 28 | 411,819 | 20 | 18 | 4 | 0 | | | | | | | | |
| | Ocean Sport | 26 | 156,528 | 19 | 20 | 0 | 0 | | | | | | | | |
| | Klamath River Net | 33 | 29,902 | 27 | 30 | 5 | 0 | | | | | | | | |
| | Klamath River Sport | 32 | 9,894 | 15 | 7 | 1 | 0 | | | | | | | | |
| | Sacramento River Sport | 3 | 75,936 | 60 | 60 | 40 | 40 | | | | | | | 1,3,4 | |
| | Other Freshwater Sport | 0 | NA | 0 | 0 | 100 | 100 | | | | | | | 1,3,4 | 1,3,4 |

Key for fishery issues:

1 Low fishery sample rates
2 Non-representative fishery sampling
3 Incomplete fishery sampling
4 Inconsistent sampling of marked and unmarked CWTs
5 Voluntary sampling programs
6 Bias in estimates of total harvest
7 Data coordination and reporting issues

Table 4-2. Chinook indicator stock CWT releases, returns to escapement at hatchery rack and spawning grounds, averaged over brood years 1994-1999, and sample rates in hatchery and natural spawning escapement averaged over run years 2000-2004. Issues are indicated and explained by notes at bottom of table.

| Indicator Stock Description | | | Average Release over BY 1994-1999 | Average Estimated CWT Recoveries in Escapement (BY 1994-1999): Hatchery | Average Estimated CWT Recoveries in Escapement (BY 1994-1999): Spawning Grounds | Proportion Escapement Sampled For CWTs return years 2000-2004: Hatchery | Proportion Escapement Sampled For CWTs return years 2000-2004: Survey of Natural Spawners: Immediate Vicinity of Hatchery | Proportion Escapement Sampled For CWTs return years 2000-2004: Survey of Natural Spawners: Within Remainder of Watershed where Hatchery is Located | Issues, see Key at Bottom of Table |
|---|---|---|---|---|---|---|---|---|---|
| Alaska | ACI | Alaska Central Inside | 60,054 | 218 | - | 45% | - | 13% | |
| | ASI | Alaska Southern Inside | 157,476 | 812 | - | 28% | - | 22% | |
| | ALP | Little Port Walter | 126,806 | 1,405 | 2 | 51% | 17% | 22% | |
| Canada | BQR | Big Qualicum R | 214,010 | 97 | 90 | 65% | 65% | 0% | |
| | CHI | Chilliwack R | 89,488 | 228 | 2,465 | 100% | 12% | 6% | 1,2,6 |
| | COW | Cowichan R | 200,206 | 83 | 268 | 64% | 14% | 0% | 2 |
| | KLM | Kitsumkalum | 204,019 | 0 | 630 | 100% | 10% | 0% | 2 |
| | PPS | Puntledge R | 188,751 | 85 | 48 | 87% | 87% | 0% | |
| | QUI | Quinsam R | 237,535 | 216 | 377 | 95% | 74% | 0% | |
| | RBT | Robertson Cr | 199,968 | 463 | 508 | 100% | 25% | 0% | |
| | DOM | Dome Cr | 74,837 | 42 | 8 | 71% | 0% | 0% | 1,2,4,8 |
| | SNO | Atnarko-summer (Snootli) | 153,580 | NA | >100 observed | NA | 0% | 0% | 6,7,8 |
| | SHU | Lower Shuswap | 94,579 | <5 | 457 | 100% | 40% | 0% | 1,7,8 |
| | NIC | Nicola | 83,844 | <20 | 487 | 100% | 47% | 0% | 1,7,8 |
| Washington | GAD | George Adams Fall Fingerling | 292,588 | 467 | 61 | 100% | 0% | 5% | 2,6 |
| | GRN | Green River Fall Fingerling | 313,235 | 314 | 172 | 96% | 56% | 14% | 3 |
| | GRO | Grovers Creek Fall Fingerling | 225,278 | 1,356 | 23 | 94% | 0% | 14% | |
| | HOK | Hoko Fall Fingerling | 157,484 | 148 | 447 | 66% | 0% | 43% | |
| | NIS | Nisqually Fall Fingerling | 273,514 | 639 | | 97% | 0% | 1% | 2 |
| | NSF | Nooksack Spring Fingerling | 218,080 | 687 | 104 | 100% | 27% | 37% | 6 |
| | NKS | Nooksack Spring Yearling | 170,664 | 109 | 11 | 100% | 27% | 37% | 6 |
| | QUE | Queets Fall Fingerling | 175,429 | 3 | 443 | 89% | 0% | 25% | 2 |
| | SAM | Samish Fall Fingerling | 253,976 | 280 | 1 | 76% | 0% | 0% | |
| | SKF | Skagit Spring Fingerling | 232,669 | 1,096 | 37 | 100% | 0% | 6% | 2,6 |
| | SKS | Skagit Spring Yearling | 167,077 | 630 | 48 | 100% | 0% | 6% | 2,6 |
| | SSF | Skagit Summer Fingerling | 162,760 | 9 | 598 | 100% | 0% | 7% | 2 |

| Indicator Stock Description | | | Average Release over BY 1994-1999 | Average Estimated CWT Recoveries in Escapement (BY 1994-1999) | | Proportion Escapement Sampled For CWTs return years 2000-2004 | | | Issues, see Key at Bottom of Table |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Survey of Natural Spawners | | |
| | | | | Hatchery | Spawning Grounds | Hatchery | Immediate Vicinity of Hatchery | Within Remainder of Watershed where Hatchery is Located | |
| | SOO | Soos Fall Fingerling-Coastal River | 214,489 | 241 | | | | | |
| | SPY | South Puget Sound Fall Yearling | 112,029 | 8 | | | | | |
| | STL | Stillaguamish Fall Fingerling | 139,575 | 56 | 295 | 96% | 0% | 20% | 6 |
| | WRF | White River Fall Fingerling | 217,747 | 480 | | 95% | 0% | 0% | 6 |
| | WHF | White River Hatchery Fingerling | 243,929 | 242 | 31 | 95% | 0% | 0% | |
| | WHY | White River Hatchery Yearling | 75,885 | 167 | | 95% | 0% | 0% | |
| | WRY | White River Spring Yearling | 77,840 | 58 | | 95% | 0% | 0% | |
| Oregon | SRH | Salmon River | 184,044 | 96 | 1,434 | 100% | 18% | 18% | 7 |
| Columbia River | LRH | Columbia Lower River Hatchery fall | 211,894 | 300 | 160 | 86% | 35% | | |
| | SUM | Columbia Summers | 753,877 | 857 | 577 | 86% | 0% | 22% | |
| | CWF | Cowlitz Tule | 223,079 | 136 | 44 | 95% | 0% | 27% | |
| | HAN | Hanford fall | 155,120 | 3 | 356 | 100% | 0% | 5% | |
| | LRW | Lewis River Wild fall | 85,027 | 2 | 141 | 85% | 0% | 35% | |
| | LYF | Lyons Ferry Fall | 332,000 | 780 | 31 | 99% | 0% | 17% | |
| | SPR | Spring Creek Tule | 423,085 | 881 | 81 | 36% | 0% | 12% | |
| | URB | Upriver Bright | 397,298 | 468 | 351 | 98% | 0% | 21% | |
| | WSH | Willamette Spring | 1,088,013 | 4,081 | 230 | 100% | 0% | 12% | 2,3,4,6,7 |
| California | SRF | Sacramento River fall Chinook | 2,487,781 | 2,849 | 4,062 | 93% | 18% | 19% | 2 |
| | SRW | Sacramento winter Chinook | 50,276 | 6 | 50 | 100% | 56% | 56% | 1 |
| | CVS | Central Valley spring Chinook | 261,875 | 359 | 827 | 100% | 5% | 12% | 2,6 |
| | KTF | Klamath River fall Chinook | 715,355 | 3,778 | 2,660 | 100% | 42% | 10% | 1 |
| | CAC | California coastal Chinook | 23,666 | 0 | 0 | 100% | 0% | 0% | 1,2,4,5,6,7 |

Key for escapement issues (see section 4.1.1. and 4.1.2):

1 Low CWT tag release numbers
2 Low esc. sample rates
3 Non-representative esc. sampling
4 Incomplete esc. sampling
5 Inconsistent sampling of marked and unmarked CWTs
6 Bias in estimates of total escapement
7 Data coordination and reporting problems
8 Currently not an indicator stock, but would be if funding available
9 Indicator stock no longer operating

Table 4-3. Coho production regions and indicator stock releases, returns to escapement at hatchery rack and spawning grounds averaged over brood years 1999-2003, and sample rates in hatchery and natural spawning escapements averaged over run years 2000-2004.

| | | | | Average Estimated CWT Recoveries (BY 1999-2003) | | Proportion Sampled For CWTs for CY 2000-2004 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Survey of Natural Spawners | | |
| Province or State | Production Regions | Indicator Stock | Average Release (Release years 1999-2003) | Hatchery Rack | Escapement and AK Cost Recovery | Hatchery | Immediate Vicinity of Hatchery or Wild Stock (Cost Recovery for AK) | Within Remainder of Watershed where Hatchery is Located | Issues - See Key at Bottom of Table |
| Alaska | N ALASKA INSIDE | HATCHERY | 444,237 | 448 | 837 | 23% | 5% | | |
| | | Auke Creek (NSEI) | 4,520 | NA | 717 | NA | 100% | | |
| | | Berners River (NSEI) | 38,800 | NA | 2,972 | NA | 9% | | |
| | | Chilkat River (NSEI) | 27,339 | NA | 1,773 | NA | 3% | | 2 |
| | | Slippery Creek (NSEI) | 17,064 | NA | 1,401 | NA | 85% | | |
| | N ALASKA OUTSIDE | HATCHERY | 79,949 | 171 | 0 | 100% | | | |
| | | Ford Arm Lake (NSEO) | 9,453 | NA | 491 | NA | 63% | | |
| | | Nakwasina River (NSEO) | 9,222 | NA | 624 | NA | 33% | | |
| | S ALASKA INSIDE | HATCHERY | 610,929 | 467 | 310 | 30% | 8% | | |
| | | Hugh Smith Lk (SSEI) | 19,105 | NA | 1,199 | NA | 96% | | |
| | S ALASKA OUTSIDE | HATCHERY | 167,596 | 86 | 34 | 6% | 9% | | 3,4,6 |
| | | Chuck Creek (SSEO) | 16,002 | NA | 449 | NA | 100% | | |
| | TRANSBOUNDARY | Taku River (TBR) | 36,438 | NA | 2,227 | NA | 2% | | 2 |
| British Columbia | BC NORTH COAST | Toboggan | 34,542 | 10 | 1,146 | 62% | 0% | 0% | 2-4,7,9 |
| | | Zolzap | 10,432 | NA | 626 | NA | 75% | 0% | 1,7,9 |
| | | Lachmach | 14,609 | NA | 555 | NA | 20% | 0% | 1,7,9 |
| | BC CENTRAL COAST | Martin River | 6,880 | NA | 60 | NA | 10% | 0% | 1-5,7,9 |
| | | West Arm Cr | 7,156 | NA | 509 | NA | 50% | 0% | 1,7 |
| | JOHNSTONE STRAIT | Quinsam | 46,332 | 255 | 530 | 83% | 83% | 0% | 4,6 |
| | | Keogh | 26,269 | NA | 406 | NA | 0% | 0% | 2-4,7 |
| | GEORGIA STR VCI | Big Qualicum | 41,346 | 411 | 189 | 46% | 0% | 0% | 4,6 |
| | | Black Creek | 10,521 | NA | 3,633 | NA | 39% | 0% | 1,7 |
| | | Goldstream | 21,561 | 28 | 552 | 100% | 42% | 0% | 7 |
| | UPPER FRASER RIVER | Coldwater River | 39,182 | 59 | 3,021 | 100% | 12% | 0% | 2 |
| | | Louis/Lemieux/Dunn Crs | 25,757 | 24 | 1,524 | 100% | UNK | 0% | 1,4,7 |

| Province or State | Production Regions | Indicator Stock | Average Release (Release years 1999-2003) | Average Estimated CWT Recoveries (BY 1999-2003) | | Proportion Sampled For CWTs for CY 2000-2004 | | | Issues - See Key at Bottom of Table |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Survey of Natural Spawners | | |
| | | | | Hatchery Rack | Escapement and AK Cost Recovery | Hatchery | Immediate Vicinity of Hatchery or Wild Stock (Cost Recovery for AK) | Within Remainder of Watershed where Hatchery is Located | |
| | LOWER FRASER RIVER | Chilliwack | 38,894 | 1,094 | 86 | 100% | 15% | 2% | 2-4,6,9 |
| | | Inch | 39,862 | 604 | 53 | 100% | 97% | 0% | |
| | SW VANCOUVER IS | Robertson | 40,316 | 1,721 | 42 | 67% | 0% | 0% | 2-4 |
| Washington | SKAGIT | Marblemount Hatchery | 109,625 | 3,400 | | 100% | | | |
| | NOOKSACK/SAMISH | Kendall Creek Hatchery | 49,537 | 600 | | 77% | | | |
| | | Lummi Sea Ponds | 46,977 | 196 | | 88% | | | |
| | | Skookum Creek Hatchery | 46,938 | 703 | | 94% | | | |
| | STILLAG/SNOHOMISH | Bernie Gobin Hatch | 30,222 | 71 | | 99% | | | 1 |
| | | Wallace River Hatchery | 42,485 | 2,133 | | 94% | | | |
| | HOOD CANAL | George Adams Hatchery | 44,556 | 1,484 | | 95% | | | |
| | | Port Gamble Bay Pens | 45,745 | | 60 | | 84% | | 2 |
| | | Quilcene Bay Sea Pen | 47,813 | 842 | 1 | 34% | 100% | | 2,4 |
| | | Quilcene NFH | 45,289 | 956 | | 41% | | | 2 |
| | S. PUGET SOUND | Soos Creek Hatchery | 82,833 | 2,472 | | 87% | | | |
| | | South Sound Net Pens | 178,601 | 645 | | 99% | | | 2,4 |
| | | Voights Creek Hatchery | 40,553 | 1,211 | | 83% | | | |
| | ST OF JUAN DE FUCA | Lower Elwha Hatchery | 149,457 | 683 | | 100% | | | |
| | MAKAH | Makah NFH | 38,120 | 634.87 | | 23% | | | 1,2 |
| | QUILLAYUTE | Solduc Hatchery | 78,008 | 1,654 | | 99% | | | |
| | QUEETS | Salmon River Fish Cult | 118,050 | 99 | 620 | 91% | 24% | | |
| | QUINAULT | Quinault NFH | 176,497 | 2,852 | 5 | 21% | 82% | | 2 |
| | GRAYS HARBOR | Bingham Creek Hatchery | 70,442 | 2 | 1 | 91% | 100% | | |
| | | Lk Aberdeen Hatchery | 49,141 | 442 | 2 | 99% | 99% | | |
| | | Satsop Springs Ponds | 32,321 | 1,373 | 63 | 98% | 90% | | 1 |
| | WILLAPA | Forks Creek Hatchery | 87,759 | 1,949 | | 99% | | | |
| | | Naselle Hatchery | 61,258 | 245 | | 73% | | | |
| Columbia River | COLUMBIA RIVER | Cede Youngs Bay Net | 169,908 | 763 | 15 | 99% | 99% | | |
| | | Cowlitz Salmon Hatch | 125,016 | 1,319 | 1 | 98% | 100% | | |

| Province or State | Production Regions | Indicator Stock | Average Release (Release years 1999-2003) | Average Estimated CWT Recoveries (BY 1999-2003) | | Proportion Sampled For CWTs for CY 2000-2004 | | | Issues - See Key at Bottom of Table |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Survey of Natural Spawners | | |
| | | | | Hatchery Rack | Escapement and AK Cost Recovery | Hatchery | Immediate Vicinity of Hatchery or Wild Stock (Cost Recovery for AK) | Within Remainder of Watershed where Hatchery is Located | |
| | | Eagle Creek NFH | 52,421 | 354 | 3 | 55% | 100% | | 2 |
| | | Elochoman Hatchery | 68,083 | 309 | 3 | 99% | 100% | | |
| | | Grays River Hatchery | 58,650 | 321 | | 86% | | | |
| | | Kalama Falls Hatchery | 113,796 | 599 | 1 | 90% | 100% | | |
| | | Klaskanine S Fk Pond | 26,035 | 26 | 3 | 97% | 100% | | 1 |
| | | North Toutle Hatchery | 67,269 | 968 | 7 | 74% | 100% | | |
| | | Oxbow Hatchery | 169,072 | 1,261 | 13 | 99% | 100% | | |
| | | Sandy Hatchery | 111,941 | 1,044 | 3 | 99% | 100% | | |
| | | Washougal Hatchery | 300,843 | 3,825 | 8 | 98% | 100% | | |
| | | Willard NFH | 56,124 | 251 | 4 | 90% | 99% | | |
| Oregon and California | OREGON N AND MID CST | Cole River Hatchery | 47,932 | 540 | 1 | 98% | 100% | | |
| | | Nehalem Hatchery | 50,608 | 753 | 63 | 99% | 95% | | |
| | | Rock Creek Hatchery | 48,332 | 144 | 2 | 94% | 100% | | |
| | | Salmon River Hatchery | 24,656 | 159 | 95 | 99% | 66% | | 1 |
| | | Trask River Ponds | 31,682 | 1,286 | 3 | 99% | 94% | | 1 |
| | OREGON S/CALIF CST | Oregon/Sth Cal Cst | 28,036 | 1,513 | 4 | 99% | 58% | | 1 |

UNK = Unknown (missing data)
1 Low CWT tag release numbers
2 Low esc. sample rates
3 Non-representative esc. sampling
4 Incomplete esc. sampling
5 Inconsistent sampling of marked and unmarked CWTs
6 Bias in estimates of total escapement
7. Data coordination and reporting problems
8 Currently not an indicator stock, but would be if funding available
9 Indicator stock no longer operating

Table 4-4. Estimated number of tagged fish harvested in fisheries as grouped by the CTC and in escapement for Chinook indicator stocks averaged over brood years 1999-2004. See Table 4.2 for full name of indicator stocks.

| Region | Stock | SEAK | NCBC Troll | NCBC Sport | BC Net | WCVI Troll | WCVI Sport | GAST Sport | WAOCN | WAPS Sport | WAPS Net | COLR Net | COLR Sport | OR Sport | OR Troll | CA | TERM | Total Escap. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alaska | ACI | 258 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 257 |
| | ALP | 928 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,237 |
| | ASI | 1,272 | 18 | 14 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,036 |
| Canada | BQR | 41 | 5 | 23 | 1 | 4 | 3 | 23 | 1 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 9 | 183 |
| | CHI | 6 | 1 | 12 | 14 | 323 | 121 | 196 | 419 | 78 | 31 | 0 | 1 | 0 | 27 | 0 | 160 | 2,658 |
| | COW | 5 | 4 | 10 | 0 | 28 | 21 | 118 | 3 | 9 | 43 | 0 | 0 | 0 | 0 | 0 | 38 | 340 |
| | KLM | 149 | 18 | 85 | 32 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 622 |
| | PPS | 13 | 1 | 24 | 2 | 1 | 2 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 125 |
| | QUI | 154 | 4 | 107 | 5 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 631 |
| | RBT | 247 | 26 | 93 | 0 | 1 | 52 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 225 | 754 |
| | SNO | 61 | 15 | 74 | 77 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 |
| Washington | GAD | 6 | 2 | 1 | 1 | 161 | 64 | 28 | 63 | 94 | 74 | 0 | 0 | 1 | 9 | 1 | 140 | 708 |
| | GRN | 8 | 8 | 4 | 1 | 143 | 41 | 40 | 53 | 131 | 103 | 0 | 0 | 0 | 6 | 0 | 389 | 519 |
| | GRO | 6 | 5 | 0 | 1 | 236 | 86 | 51 | 69 | 147 | 89 | 0 | 0 | 1 | 20 | 0 | 3 | 1,600 |
| | HOK | 105 | 29 | 9 | 0 | 3 | 7 | 13 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 596 |
| | NIS | 1 | 0 | 1 | 0 | 108 | 44 | 25 | 56 | 238 | 14 | 0 | 0 | 0 | 8 | 0 | 728 | 874 |
| | NKS | 0 | 0 | 1 | 2 | 5 | 2 | 16 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 48 |
| | NSF | 35 | 3 | 7 | 1 | 208 | 63 | 67 | 13 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 3 | 1,031 |
| | QUE | 310 | 80 | 79 | 0 | 4 | 4 | 1 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 215 | 461 |
| | SAM | 5 | 5 | 3 | 1 | 141 | 62 | 84 | 42 | 75 | 597 | 0 | 0 | 0 | 2 | 0 | 8 | 509 |
| | SKF | 28 | 4 | 19 | 6 | 87 | 84 | 106 | 5 | 41 | 3 | 0 | 0 | 0 | 0 | 0 | 8 | 1,133 |
| | SKS | 3 | 2 | 9 | 0 | 150 | 58 | 96 | 3 | 130 | 10 | 0 | 0 | 0 | 0 | 0 | 7 | 815 |
| | SOO | 58 | 22 | 12 | 0 | 1 | 6 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 241 |
| | SPY | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 44 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 6 |
| | SSF | 105 | 13 | 31 | 1 | 66 | 46 | 47 | 2 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 5 | 607 |
| | STL | 10 | 2 | 2 | 1 | 27 | 18 | 15 | 1 | 19 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 310 |
| | WHF | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 97 |
| | WHY | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 67 |
| | WRF | 0 | 0 | 0 | 0 | 18 | 6 | 10 | 4 | 18 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 288 |
| | WRY | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 25 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| Oregon | SRH | 568 | 142 | 68 | 0 | 9 | 5 | 0 | 9 | 0 | 0 | 0 | 0 | 56 | 41 | 0 | 950 | 1,629 |

| Region | Stock | SEAK | NCBC Troll | NCBC Sport | BC Net | WCVI Troll | WCVI Sport | GAST Sport | WAOCN | WAPS Sport | WAPS Net | COLR Net | COLR Sport | OR Sport | OR Troll | CA | TERM | Total Escap. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Columbia River | CWF | 16 | 3 | 1 | 0 | 24 | 15 | 1 | 70 | 0 | 0 | 12 | 8 | 2 | 38 | 0 | 7 | 179 |
| | HAN | 154 | 32 | 10 | 0 | 11 | 4 | 0 | 5 | 0 | 0 | 157 | 69 | 1 | 5 | 0 | 5 | 359 |
| | LRH | 1 | 0 | 0 | 0 | 90 | 54 | 2 | 106 | 1 | 1 | 45 | 5 | 9 | 63 | 1 | 23 | 428 |
| | LRW | 47 | 12 | 5 | 0 | 22 | 10 | 0 | 14 | 0 | 0 | 16 | 7 | 0 | 8 | 0 | 4 | 397 |
| | LYF | 26 | 18 | 1 | 0 | 57 | 4 | 0 | 113 | 0 | 0 | 68 | 18 | 2 | 31 | 1 | 16 | 763 |
| | SPR | 0 | 0 | 0 | 0 | 211 | 85 | 6 | 291 | 11 | 0 | 750 | 10 | 22 | 254 | 4 | 83 | 945 |
| | SUM | 1,309 | 397 | 154 | 3 | 725 | 132 | 8 | 366 | 11 | 0 | 106 | 190 | 35 | 325 | 13 | 5 | 1,433 |
| | URB | 278 | 45 | 29 | 0 | 19 | 13 | 3 | 28 | 0 | 0 | 305 | 110 | 1 | 7 | 0 | 19 | 819 |
| | WSH | 370 | 39 | 7 | 0 | 115 | 20 | 0 | 45 | 5 | 0 | 958 | 473 | 2 | 40 | 1 | 2,554 | 9,636 |
| California | SRF | 1 | 0 | 1 | 0 | 21 | 21 | 0 | 47 | 62 | 0 | 2 | 0 | 257 | 2,007 | 3,861 | 1,162 | 6,911 |
| | SRW | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 5 | 27 | 56 |
| | CVS | 0 | 0 | 0 | 0 | 4 | 2 | 0 | 9 | 8 | 0 | 0 | 0 | 56 | 476 | 845 | 324 | 1,186 |
| | KTF | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 53 | 410 | 671 | 403 | 6,438 |
| | CAC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 29 | 0 | 0 |

Table 4-5. Estimated harvest by fisheries for tagged coho salmon used as representatives for production regions averaged over brood years 1995-1999. The same fishery groups used for Chinook in Figure 4-4 are used here for coho.

| Production Region | | SEAK | NCBC Troll & Net | NCBC Sport | WCVI Net | WCVI Sport | GAST Sport | WAOCN | WAPS Sport | WAPS Troll & Net | COLR Net | COLR Sport | OR Sport | OR Troll | CA | TERM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alaska | N ALASKA INSIDE H | 8,283 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15,783 |
| | N ALASKA OUTSIDE H | 1,595 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | S ALASKA INSIDE H | 14,453 | 79 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,702 |
| | S ALASKA OUTSIDE H | 1,841 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 939 |
| | Auke Creek (NSEII) | 374 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Berners River (NSEI) | 2,954 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Chilkat River (NSEI) | 1,152 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Chuck Creek (SSEO) | 715 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Ford Arm Lake (NSEO) | 728 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Hugh Smith Lk (SSEI) | 1,134 | 37 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Nakwasina River (NSEO) | 243 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Slippery Creek (NSEI) | 1,065 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Taku River (TBR) | 1,005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| British Columbia | BC NORTH COAST | 788 | 121 | 188 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 621 |
| | BC CENTRAL COAST | 27 | 8 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | JOHNSTONE STRAIT | 11 | 3 | 157 | 0 | 12 | 17 | 1 | 8 | 4 | 0 | 0 | 1 | 0 | 0 | 10 |
| | GEO STR VANC ISL | 4 | 3 | 106 | 0 | 75 | 70 | 13 | 89 | 39 | 0 | 1 | 6 | 1 | 0 | 31 |
| | UPPER FRASER RIVER | 0 | 0 | 0 | 0 | 12 | 9 | 21 | 44 | 13 | 0 | 1 | 11 | 0 | 0 | 0 |
| | LOWER FRASER RIVER | 2 | 0 | 0 | 0 | 42 | 57 | 25 | 115 | 59 | 0 | 0 | 5 | 0 | 0 | 304 |
| | SW VANCOUVER ISL | 2 | 4 | 22 | 32 | 830 | 28 | 7 | 22 | 14 | 0 | 0 | 2 | 0 | 0 | 17 |
| Washington | SKAGIT | 1 | 2 | 12 | 0 | 59 | 94 | 269 | 1,401 | 278 | 0 | 5 | 95 | 2 | 0 | 1,455 |
| | NOOKSACK/SAMISH | 3 | 1 | 14 | 0 | 32 | 77 | 90 | 311 | 1,825 | 0 | 2 | 33 | 3 | 0 | 154 |
| | STILLAG//SNOHOM | 0 | 0 | 7 | 0 | 30 | 18 | 145 | 553 | 1,460 | 0 | 2 | 56 | 4 | 0 | 7 |
| | HOOD CANAL | 2 | 1 | 10 | 0 | 53 | 27 | 110 | 1,236 | 756 | 0 | 1 | 52 | 5 | 0 | 217 |
| | S PUGET SOUND | 4 | 1 | 12 | 0 | 135 | 54 | 333 | 2,087 | 3,573 | 0 | 6 | 118 | 7 | 0 | 3,952 |
| | STR OF JDF | 21 | 1 | 19 | 0 | 3 | 6 | 24 | 50 | 28 | 1 | 4 | 4 | 0 | 0 | 225 |
| | MAKAH COASTAL | 2 | 2 | 0 | 0 | 15 | 4 | 52 | 36 | 14 | 1 | 3 | 19 | 1 | 0 | 61 |
| | QUILLAYUTE | 4 | 2 | 0 | 0 | 24 | 0 | 133 | 24 | 51 | 0 | 2 | 62 | 9 | 0 | 5 |
| | QUEETS | 1 | 1 | 0 | 0 | 4 | 0 | 201 | 21 | 28 | 0 | 5 | 83 | 9 | 0 | 914 |

| Production Region | | SEAK | NCBC Troll & Net | NCBC Sport | WCVI Net | WCVI Sport | GAST Sport | WAOCN | WAPS Sport | WAPS Troll & Net | COLR Net | COLR Sport | OR Sport | OR Troll | CA | TERM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | QUINAULT | 6 | 5 | 18 | 0 | 54 | 5 | 626 | 99 | 57 | 0 | 21 | 228 | 19 | 0 | 3,674 |
| | GRAYS HARBOR | 2 | 2 | 0 | 0 | 20 | 0 | 373 | 10 | 13 | 1 | 9 | 61 | 16 | 0 | 345 |
| | WILLAPA BAY | 2 | 3 | 10 | 0 | 22 | 9 | 2,347 | 44 | 32 | 9 | 30 | 352 | 29 | 0 | 3 |
| Columbia R. | COLUMBIA RIVER | 0 | 0 | 7 | 0 | 90 | 3 | 3,163 | 154 | 68 | 8,931 | 2,368 | 2,805 | 208 | 28 | 18 |
| Oregon and California | OR N AND MID CST | 1 | 0 | 0 | 0 | 0 | 0 | 170 | 13 | 3 | 4 | 36 | 421 | 19 | 14 | 33 |
| | OR S/CALIFORNIA CST | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 18 | 1 | 3 | 2 |

## *4.2 Summary of Tagging and Sampling for Chinook and Coho Salmon Indicators*

The workgroup developed a tool to examine the current status of Chinook and coho tagging and sampling programs. This tool used criteria set by the PSC technical committees or the CWT workgroup, and the information summarized for tagging and sampling issues for Chinook and coho indicators in Table 4-1 to Table 4-5. The output from the tool is a summary evaluation table, which provides an overview of the performance of current tagging and sampling efforts relative to the standards and precision criteria developed by the CTC, CoTC and the CWT workgroup.

The table is a matrix of rows representing Chinook indicator stocks or coho regional groups and columns representing either tag release size or recovery sampling locations. The status for each cell is represented by an index of 1 (green cell), 2 (yellow cell) or 3 (red cell). In order to receive a status of 1 (or a green light) all criteria must be met, if one criterion is not met the cell receives a status of 2 (yellow) and if 2 or more criteria are not met, then the cell receives a status of 3 (red). However, the initial test for all cells representing fishery sampling (columns 3 and higher) is whether a minimum proportion of the total tagged fish of that stock was present in a fishery. If the percent distribution is less than 2.5% then the cell will be blank for that stock-fishery combination. An average percent distribution of 2.5% was chosen as a minimum by the CWT workgroup in order to provide an overview of the fishery areas where a stock is likely to be present.

In order to provide an overview, the tool evaluates several criteria simultaneously to identify areas with stocks and/or fisheries where further evaluation is necessary based on the following criteria:

1. Release size. For each tagged stock or production region, was the release size at or above the minimum guideline (200K for Chinook; 40K-75K for coho)?
2. Recoveries in escapements. For escapement, was the sample rate above 20%, was the escapement estimated with a percent standard error (PSE) that does not exceed 20%, and was the minimum number of observed recoveries achieved (20 for Chinook all ages combined and 10 for coho salmon – see discussion on precision in Chapter 5)?.
3. Recoveries in fisheries. For each stock, did the fishery strata account for at least 2.5% of the recoveries?
4. Fishery sampling. Was the fishery sampled?
5. Fishery sampling rate. If the fishery is sampled, then were at least 20% of the fish examined for CWTs, was the harvest estimated with a PSE that does not exceed 20%, and was the minimum number of recoveries observed (20 for Chinook all ages combined and 10 for coho salmon – see discussion on precision in Chapter 5)?

### 4.2.1 CWT Release Sizes

Survival, patterns of fishery exploitation, acceptable levels of uncertainty surrounding ER estimates for specific fisheries, the accuracy of catch and escapement estimates, and the design of sampling programs all influence the determination of the required size of CWT

releases. A universal standard release size is not be suitable for all circumstances. Chapter 6 of this report describes a tool that can help evaluate interactions among these factors when establishing target CWT release sizes.

The simple general release criterion is currently 200K tags per indicator group for Chinook salmon (originally developed for fall Chinook hatchery releases) and 40-75K for coho salmon. Given the standard target of 20 (Chinook salmon) or 10 (coho salmon) observed tags per stratum to meet minimum precision criteria for an estimate of total tags or ER, the stock's survival will influence whether releases are adequate. For Chinook salmon a minimum of 20 tags was the criteria used, representing roughly 10 tags from each of two major age classes (e.g., age 3- and 4-ocean-age fish). However, some stocks have consistently demonstrated higher survival rates in recent years and have been tagged at a lower rate. So we developed graduated criteria to accommodate stocks with better survival rates (Figure 4-1). The criteria show the necessary survival needed with different release sizes to expect 10 or 20 recovered tags given a 2.5% ER and a 20% sampling rate.

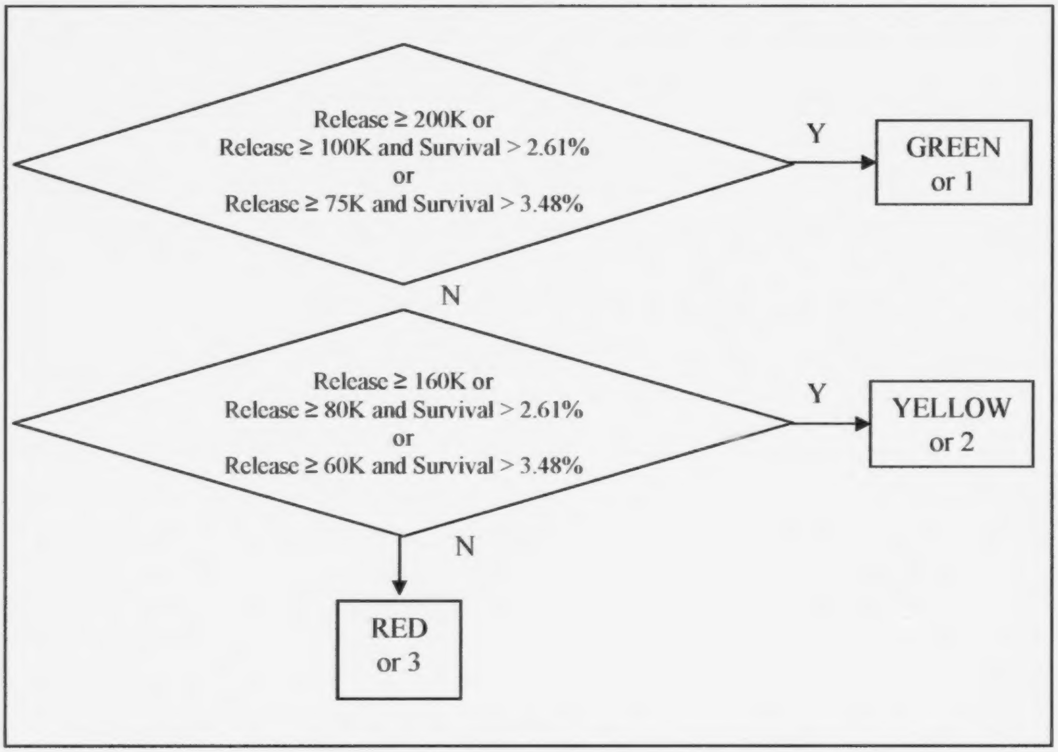


Figure 4-1. Flow chart showing how release criteria were used to identify a color for each Chinook indicator stock.

### 4.2.2 Sampling Programs

The criteria used to assess hatchery and spawning ground escapement and fishery sampling efforts were guided by sampling rates, PSE of estimated tags, and the number of tags observed (Table 4-6 and Table 4-7).

Table 4-6. Benchmark parameters and criteria used to evaluate CWT sampling and estimation performance.

| Benchmark Parameter | Criteria |
|---|---|
| Sampling Rate | 20% for fisheries |
| Percent Standard Error in Estimated Tags | 30% |
| Number of Observed Tags | 20 for Chinook all ages and 10 for coho salmon |

Table 4-7. The PSE index (1<30%, 2 >30% and <50%) and the sampling rate identified for each fishery for Chinook salmon.

| **Fishery** | **PSE/1** | **Sampling Rate** |
|---|---|---|
| AK Terminal Commercial | Varies by stock | Varies by stock |
| AK Terminal Native | Varies by stock | Varies by stock |
| AK Terminal Sport | Varies by stock | Varies by stock |
| SEAK Troll | 1 | 36% |
| SEAK Sport | 1 | 19% |
| SEAK Net | 1 | 20% |
| NCBC Troll | 1 | 36% |
| NCBC Sport | 2 | 12%[2] |
| NCBC Net | 2 | 39% |
| WCVI Troll | 1 | 31% |
| WCVI Sport | 2 | 7%[2] |
| Georgia Strait Troll | 1 | 17% |
| Georgia Strait Sport | 2 | 17%[2] |
| South BC Net | 2 | 50% |
| WA Ocean Troll | 1 | 41% |
| WA Ocean Sport | 1 | 43% |
| PS Sport | 1 | 20% |
| WA Net | 1 | 39% |
| Col River Sport | 2 | 18% |
| Col River Net | 1 | 42% |
| OR Coast Troll | 1 | 22% |
| OR Coastal Sport | 1 | 43% |
| CA Troll | 1 | 28% |
| CA Sport | 2 | 22% |

/1 Issues of bias (e.g., due to unreported catch) are not considered by this statistic.
/2 Estimated from voluntary sport programs.

The PSE index was developed by the workgroup, with regional members providing input as to the average precision of estimates of total fish in escapement and harvest. If at least 2.5% of the total return (escapement+fishery) occurred in a recovery location, then green (status 1) was achieved if all three criteria were met, yellow (status 2) if two out of three were met, and red (status 3) otherwise.

### 4.2.3 Summary Evaluation Tables

The summary evaluation tables for Chinook and coho salmon are given in Figure 4-2 and Figure 4-3 respectively. For Chinook the stocks are the tagged indicator stocks, while for coho the stocks are the tagged groups that the CoTC uses for each production region. Each row in the table represents an indicator stock (Chinook salmon) or production region (coho salmon) and for each stock there is a cell for release size, quality of data for hatchery and spawning ground sampling, terminal commercial, sport and aboriginal fisheries (in Canada) and for pre-terminal or mixed stock fisheries. The pre-terminal fisheries were those used by the CTC. The first five columns pertain to stock specific issues, i.e., sampling in escapement or terminal fisheries, while the remaining columns relate to mixed-stock fishery issues. Each cell represents a specific release or sampling location for a specific stock. Examining cells across a row shows the quality of CWT data for a stock across release and sampling locations, while examining cells down a column shows the quality of data collected from a specific location (e.g., a fishery) over all the stocks present at that location.

These tables summarize the condition of the CWT program among stocks and fisheries with respect to the precision of the CWT estimates. The workgroup members used the tables to develop regional evaluations of tagging and sampling programs. The tables do not provide information on potential bias in estimates of tagged harvest or escapement or estimates of ERs. Knowledge of the workgroup members and agency staff as to how well sample design criteria for sample strata and assumptions about strata are met were used to identify potential bias in estimates.

## *4.3 Summary and Recommendations*

Figure 4-2 and Figure 4-3 summarize the current status of the CWT program for Chinook and coho salmon. These are matrices with the rows having a stock orientation and the columns having a fishery or escapement location orientation. Each cell is a stock-release location, stock-fishery, or stock-escapement location combination. Examination of a row provides a picture of the stock performance. A row with a large number of cells with status 2 (yellow) or 3 (red) indicates that the CWT group for that stock is not providing adequate information for the estimation of ERs. Examination of a column provides information on the sampling in an escapement or fishery location. A column with a large number of status 2 or 3 cells indicates substantial sampling issues with the fishery. Workgroup members used these matrices along with Table 4-1 to Table 4-3 in their evaluation of tagged stocks and fisheries and escapement sampling in their regions. The results of these examinations are presented below and in Chapter 7 and Appendix A.

### 4.3.1 Alaska

Examination of Figure 4-2 and Figure 4-3 do not indicate any substantial issues with the Chinook or coho salmon CWT programs. There are adequate number of fish released and fish sampled in escapement and fisheries indicated by a status number 1 (green cells) in all cells with the exception of SEAK sport. The status 2 for this fishery is due to a sample rate under 20%. However, for the fishery years 2000-2004 the annual sample rate has averaged 19% and the number of tags recovered in the fishery is well over 20 tags for the indicator stock(s). The SEAK net fisheries, specifically purse seine, do not meet the coastwide standard of 20% sampling for Chinook and coho salmon.

### 4.3.2 British Columbia

For BC Chinook and coho indicator stocks, release sizes should be reviewed due to low survival rates and escapement spawning sampling appears adequate. The primary stock issue is the absence of indicator stocks in central BC and Fraser River. In fisheries, issues with the sport fishery sampling programs, mainly low sampling rates and biased catch estimates, account for the majority of the red status cells in BC ocean fisheries. Also, these fisheries have "voluntary" sampling, i.e., anglers send in heads from fish that are clipped, which provides high potential for biases in the CWT data. These fisheries represent a high percentage of total tagged fish harvested for many BC and Washington stocks (Table 4-4 and Table 4-5), and improvements are needed to recover sufficient tags to meet the guidelines. In addition unmarked, tagged fish are not recovered in these fisheries. Terminal fisheries (both Native and non-Native) are not sampled adequately, and these programs need to be developed or improved to coastwide guidelines.

### 4.3.3 Washington Coast and Puget Sound

Examination of Washington Coast and Puget Sound Chinook indicator stocks indicates that the CWT release size should be reviewed due to low survival rates. In addition, for some stocks, sampling on the spawning grounds and in terminal fisheries, and estimation of catch and escapement, should also receive some attention (see Appendix A). For Puget Sound stocks, improvements are needed in sampling sport fisheries in BC and Puget Sound to recover at least 20 tags for all ages combined.

Figure 4-3 for coho indicates that improvements are needed in sampling of terminal freshwater (in contrast, terminal sport fisheries for Chinook have substantially lower impacts and often account for less than 2.5% of CWT recoveries for individual stocks) and in escapement sampling and estimation. In addition, for Puget Sound coho stocks, fishery sampling programs in the Strait of Georgia and in Puget Sound sport and Washington coastal net fisheries result in fewer than 10 observed recoveries. Methods of estimation of escapement for coho stocks in Puget Sound should be reviewed (Appendix A).

| STOCK INFORMATION | | Key Issues | | | | | | REGIONAL MARINE FISHERIES — Fishery Specific Key Issues | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Region | Stock | Release | Escapement (Hatcher | Escapement (Sp Grou | Term Com | Term Native | Term Sport | SEAK TR | SEAK Sport | SEAK Net | NCBC Troll | NCBC Sport | NCBC Net | WCVI Troll | WCVI Sport | Geo Strait Troll | Geo Strait Sport | SBC Net | WAOcn Troll | WA Ocn Sport | PS Sport | WA Net | Col Riv Sport | Col Riv Net | OR Coast Troll | OR Coastal Sport | CA Troll | CA Sport |
| Alaska | Alaska Central Inside | 1 | 1 | 1 | | | | 1 | 2 | | | | | | | | | | | | | | | | | | | |
| | Little Port Walter | 1 | 1 | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | Alaska Southern Inside | 1 | 1 | 1 | 1 | | | 1 | 2 | | | | | | | | | | | | | | | | | | | |
| Canada | Big Qualicum | 1 | 1 | | 3 | 3 | 3 | 2 | | | | 3 | | | | | 3 | | | | | | | | | | | |
| | Chilliwack (Harrison Fall Stock) | 2 | | 2 | | 3 | | | | | | | | 1 | 3 | | 2 | | 1 | | | | | | | | | |
| | Cowichan | 1 | 1 | | | 3 | 3 | | | | | | | 2 | 3 | | | | | | | 2 | | | | | | |
| | Kitsumkalum | 1 | | | | 3 | 3 | 1 | | | | 3 | 3 | | | | | | | | | | | | | | | |
| | Puntledge | 2 | 1 | | 3 | 3 | 3 | 2 | | | | 3 | | | | | 3 | | | | | | | | | | | |
| | Quinsam | 1 | 1 | 1 | 3 | 3 | 3 | 1 | | | | 3 | | | | | | | | | | | | | | | | |
| | Robertson Creek | 2 | 1 | 1 | 1 | 2 | 3 | 1 | | | | 3 | | | 3 | | | | | | | | | | | | | |
| | Snootli | 3 | | | 3 | 3 | 3 | 2 | | | 2 | 3 | 2 | | | | | | | | | | | | | | | |
| Washington | George Adams Fall Fingerling | 1 | 1 | 3 | 2 | | 3 | | | | | | | 1 | 3 | | | | 1 | | 1 | 2 | | | | | | |
| | Green River Fall Fingerling | 1 | 1 | 2 | 1 | | | | | | | | | 1 | 3 | | 3 | | 2 | | 1 | 1 | | | | | | |
| | Grovers Creek Fall Fingerling | 1 | 1 | | | | | | | | | | | 1 | 3 | | | | 1 | | 1 | 1 | | | | | | |
| | Hoko Fall Fingerling | 3 | 1 | 2 | | | | 1 | | | 2 | | | | | | | | | | | | | | | | | |
| | Nisqually Fall Fingerling | 1 | 1 | | 1 | | 3 | | | | | | | 1 | | | | | | | 1 | | | | | | | |
| | Nooksack Spring Yearling | 1 | 1 | | | | | | | | | | | 2 | | | 3 | | | | | | | | | | | |
| | Nooksack Spring Fingerling | 2 | 1 | 2 | | | | 2 | | | | | | 1 | 3 | | 3 | | | | | | | | | | | |
| | Queets Fall Fingerling | 2 | | 3 | 1 | | | 1 | | | 1 | 3 | | | | | | | | | | | | | | | | |
| | Samish Fall Fingerling | 1 | 1 | | | | 3 | | | | | | | 1 | 3 | | 3 | | 2 | | 2 | 1 | | | | | | |
| | Skagit Spring Fingerling | 1 | 1 | | | | | | | | | | | 1 | 3 | | | | | | 2 | | | | | | | |
| | Skagit Spring Yearling | 2 | 1 | | | | | | | | | | | 1 | 3 | | | | | | 1 | | | | | | | |
| | Sooes Fall Fingerling | 2 | 1 | | 2 | | | 2 | | | 2 | 3 | | | | | | | | | | | | | | | | |
| | South Puget Sound Fall Yearling | 1 | 2 | | 2 | | | | | | | | | | 3 | | | | | | 2 | 2 | | | | | | |
| | Squaxin Pens Fall Yearling | 3 | | | 2 | | | | | | | | | 2 | | | | | | | 1 | 2 | | | | | | |
| | Skagit Summer Fingerling | 3 | | | | | | 1 | | | | 3 | | 2 | 3 | | 3 | | | | | | | | | | | |
| | Stillaguamish Fall Fingerling | 3 | 1 | 2 | | | | | | | | | | 2 | 3 | | 3 | | | | 2 | | | | | | | |
| | White River Hatchery Fingerling | 1 | 1 | 3 | | | | | | | | | | | | | | | | | 2 | | | | | | | |
| | White River Hatchery Yearling | 1 | 1 | | | | | | | | | | | | | | | | | | 2 | | | | | | | |
| | White River Fall Fingerling | 3 | 1 | | | | | | | | | | | 2 | | | | | | | 2 | | | | | | | |
| | White River Spring Yearling | 3 | 1 | | | | | | | | | | | | | | | | | | 2 | | | | | | | |
| Oregon | Salmon River | 2 | | 1 | | | 2 | 1 | | | 1 | | | | | | | | | | | | | | | | | |
| Columbia River | Cowlitz Tule | 1 | 1 | 3 | | | | 2 | | | | | | 2 | 3 | | | | 2 | 2 | | | | 2 | 2 | | | |
| | Hanford Wild | 1 | | 2 | | | | 1 | | | 2 | | | | | | | | | | | | | 1 | | | | |
| | Columbia Lower River Hatchery | 1 | 1 | | | | | | | | | | | 1 | 3 | | | | 1 | 2 | | | | 1 | 1 | | | |
| | Lewis River Wild | 3 | | | | | | 2 | | | 2 | | | 2 | 3 | | | | 2 | | | | | 2 | 2 | | | |
| | Lyons Ferry | 3 | | | | | | | | | | | | 2 | | | | | 1 | 1 | | | | 1 | 2 | | | |
| | Spring Creek Tule | 1 | 1 | | | | | | | | | | | 1 | 3 | | | | 1 | 1 | | | | 1 | 1 | | | |
| | Columbia Summers | 1 | 1 | | | | | 1 | | | 1 | 3 | | 1 | 3 | | | | 1 | | | | | | 1 | | | |
| | Upriver Bright | 1 | 1 | | | | | 1 | | | 2 | | | | | | | | | | | | | 1 | | | | |
| | Willamette Spring | 1 | 1 | | | | 2 | 1 | | | | | | | | | | | | | | | | 1 | | | | |
| California | Sacramento falls | 1 | 1 | 3 | | | 3 | | | | | | | | | | | | | | | | | | 1 | | 1 | 2 |
| | Sacramento winters | 3 | 1 | 1 | | | 3 | | | | | | | | | | | | | | | | | | | | | 3 |
| | central valley spring | 1 | 1 | 3 | | | 3 | | | | | | | | | | | | | | | | | | 1 | | 1 | 2 |
| | Klamath-Trinity falls | 1 | 1 | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | 1 | |
| | California coast | 3 | 3 | 3 | | | | | | | | | | | | | | | | | | | | | | | 2 | 3 |

Figure 4-2 Results of evaluating tagging and fishery and escapement sampling levels using criteria set by workgroup for Chinook salmon. A blank cell indicates a fishery did not represent over 2.5% of the total exploitation for a stock. Green (1), yellow (2), or red (3) cells represent different situations with respect to the criteria as noted below; corresponding numbers are useful for black and white reproduction.

indicates that all criteria were met

indicates that one criteria is not met

indicates that two or more criteria are not met

| STOCK INFORMATION | | | | | | | | REGIONAL MARINE FISHERIES | | | | | | | | | | | | | | | | | | | | | | |
| | | Key Issues | | | | | | Fishery Specific Key Issues | | | | | | | | | | | | | | | | | | | | | | |
| Region | Stock | Release | Escapement (H) | Escapement (N) | Term Com | Term Native | Term Spt | SEAK TR | SEAK SPT | SEAK Net | NCBC Troll | NCBC Sport | NCBC Net | WCVI Troll | WCVI Sport | Geo Strait Troll | Geo Strait Spt | SBC Net | WAOcn Troll | WA Ocn Sport | PS Sport | WA Net | Col Riv Sport | Col Riv Net | OR Coast Troll | OR Coastal Sport | CA Troll | CA Sport |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Southeast Alaska | N Alaska Inside | 1 | 1 |  | 1 |  |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | N Alaska Outside | 1 | 1 |  |  |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | S Alaska Inside | 1 | 1 |  | 1 |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | S Alaska Outside | 1 | 2 |  | 1 |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Auke Creek (NSEII) Wild | 1 |  | 1 |  |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Berners River (NSEI) Wild | 1 |  | 2 |  |  |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Chilkat River (NSEI) Wild | 1 |  | 2 |  |  |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Chuck Creek (SSEI) Wild | 1 |  | 1 |  |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Ford Arm Lake (NSEO) Wild | 1 |  | 1 |  |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Hugh Smith Lk (SSEI) Wild | 1 |  | 1 |  |  |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Nakwasina River (NSEO) Wild | 1 |  | 1 |  |  |  | 1 | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Slippery Creek (NSEI) Wild | 1 |  | 1 |  |  |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Taku River (TBR) Wild | 2 |  | 2 |  |  |  | 1 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| British Columbia | BC North Coast | 1 | 1 |  | 3 | 3 | 2 | 1 | 1 | 3 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | BC Central Coast | 3 | 3 |  | 2 | 2 | 3 | 2 |  | 3 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| | Johnstone Strait | 1 | 1 |  | 3 | 3 |  |  |  |  |  | 3 |  |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  |
| | Georgia Strait - Vancouver Islan | 1 | 1 |  | 3 | 3 |  |  |  |  |  | 3 |  |  | 3 |  | 3 | 2 | 2 |  |  |  |  |  |  |  |  |  |
| | U Fraser River | 1 | 3 |  | 3 | 3 | 3 |  |  |  |  |  |  |  | 3 | 2 | 2 | 2 | 2 |  |  |  | 2 |  |  |  |  |  |
| | L Fraser River | 1 | 3 | 2 | 3 | 3 | 3 |  |  |  |  |  |  |  |  |  | 3 | 2 |  |  |  |  |  |  |  |  |  |  |
| | SW Vancouver Island | 1 | 1 |  | 3 | 3 |  |  |  |  |  |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Washington | Skagit River | 1 | 1 |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  | 1 |  | 1 |  |  |  |  |  |  |
| | Nooksack/Samish Rivers | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  | 1 |  |  |  |  |  |  |
| | Stillaguamish/Snohomish Rivers | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  | 1 |  | 1 |  |  |  |  |  |  |
| | Hook Canal | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  | 1 |  |  |  |  |  |  |
| | S Puget Sound | 1 | 1 |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  | 1 |  |  |  |  |  |  |
| | Strait of Juan de Fuca | 1 | 1 |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  |  |  |  |  |  |  |  |  |  |
| | Makah Coastal | 1 | 1 |  | 3 |  | 3 |  |  |  |  |  |  |  |  |  |  | 2 |  | 1 |  |  |  |  |  |  |  |  |
| | Quillaute River | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  | 1 | 1 |  |  |  |  |  | 1 |  |  |
| | Queets River | 1 | 1 |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |  |  |
| | Quinault River | 1 | 1 |  | 1 |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |  |  |
| | Grays Harbor | 1 | 1 |  | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 1 |  |  |  |  |  |  |
| | Willapa Bay | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  | 1 |  |  |  | 1 |  |  |
| Columbia River | Columbia River | 1 | 1 |  |  |  | 3 |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  | 1 |  | 1 |  |  |
| Oregon | Oregon N and Mid Coast | 1 | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |  |  |  |  |  | 1 |  |  |
| Oregon/California | Oregon S and California Coast | 2 | 1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Figure 4-3 Results of evaluating tagging and fishery and escapement sampling levels using criteria set by workgroup for coho salmon. A blank cell indicates a fishery did not represent over 2.5% of the total exploitation for a stock. Green (1), yellow (2), or red (3) cells represent different situations with respect to criteria as noted below; corresponding numbers are useful for black and white reproduction.

indicates that all criteria were met
indicates that one criteria is not met
indicates that two or more criteria are not met

### 4.3.4 Oregon

Oregon coastal Chinook represented by Salmon River, are largely exploited in terminal sport and SEAK fisheries. Figure 4-3 does not indicate any issues with Oregon coho releases and recovery programs. However, Oregon has some major issues with data coordination, validation, and reporting. Table 4-1 shows that Oregon does not report sample strata with zero sampling in catch or escapement indicating that all fishery and escapement locations are sampled, which seems unlikely. There are also reported problems with sampling, updating, and validation of catch-sample and tag recovery information as the data items required to be sampled and reported to the RMIS system has changed with the introduction of MM and MSFs.

### 4.3.5 Columbia River

Columbia River fisheries and escapement locations are sampled by WDFW and ODFW, but all data are reported by ODFW. These data have therefore suffered the same sampling and data coordination problems reported for Oregon above. Two Columbia River Chinook stocks, Cowlitz Tules and Lewis River wild, do not seem to provide adequate information overall, in that the number of tags observed in fisheries and escapement is under the 20 tag minimum. Most of the fisheries where these stocks are exploited are sampled over 20% so this is a problem of inadequate numbers released given their survival rates.

### 4.3.6 California

In 2006, a program to mark 25% of the Chinook production from the California Central Valley hatcheries was implemented along with increased monitoring for CWT recoveries in spawning ground surveys, sampling in the river recreational fishery, and river escapement age structure analysis. This program has the potential to greatly improve the data available to perform cohort analyses and estimate ocean ER for Central Valley Chinook salmon, provided that these programs continue into the future. Under this program, an additional eight million smolts are CWT'd annually in the Central Valley. Ocean sampling programs for both sport and commercial fisheries are designed to sample at the targeted rate of 20%. Additional funding has been made available to process and report the increased number of heads expected to be collected in these fisheries along with those collected from the spawning ground surveys and hatcheries.

For sampling of ocean recreational fisheries, difficulties exist in the estimation of catch from sport boats that use private docks and marinas. However there is an effort underway to improve these estimates. For the ocean troll fishery, CA is unable to quantify non reported landings and is experiencing difficulty with cross porting of CWTs among the management areas. In the Klamath River recreational fishery, harvest estimates do not include the recovery of CWT's in the upper river areas during most years. This is due to a combination of funding limitations and difficulty of gaining access to private land.

Although not captured in the summary data presented here, one of the two hatcheries that produce Klamath Fall Chinook, Iron Gate Hatchery, has a very low tag rate of around

5%. The Trinity River Hatchery on the Klamath has implemented a constant fractional mark rate of 20%.

Of the three endangered species act (ESA) listed Chinook stocks in CA, the Coastal Chinook evolutionary significant unit (ESU) has the least amount of population data available. No CWT indicator stock has been established for this ESU. Winter Chinook have low recovery rates at the only hatchery producing the stock, however, this is due to the hatchery genetic management plan that limits the use of hatchery produced fish in spawning. The entire hatchery production of winter Chinook is marked with CWT's and adipose fin clips.

No CWT indicator stocks have been established for ESA-listed California coho stocks, however, ocean fisheries are believed to have minimal impact on these stocks. Retention of coho has been prohibited off California for several years and retention of coho with intact adipose fins has not been permitted off Oregon.

There is a continuing need for coordinated oversight for all CA salmon management activities from production and water management through harvest and escapement.

# 5 Criteria for Precision and Accuracy

In its 1995 report, the ASFEC defined *viability* of the CWT program in terms of the following three specific characteristics:

- *it must provide the ability to use CWT data for assessment and management of wild stocks of coho and Chinook salmon;*
- *it must provide the ability to estimate stock-specific ERs by fishery and age; and*
- *it must be maintained such that the uncertainty in stock and fishery assessments and their applications does not unacceptably increase management risk.*

The first characteristic reflects the emphasis of PSC management on the conservation of wild stocks of Chinook and coho salmon. The major issue regarding the use of CWTs for this purpose is the selection of CWT release groups that have exploitation patterns that represent wild stocks. Because of costs and logistical issues of tagging and recovering sufficient numbers of wild smolts, the usual practice is to apply CWTs to groups of hatchery fish from appropriate brood stocks and release strategies as surrogates for wild fish. The second characteristic explicitly refers to ERs as the principal statistics of interest.[3] Essentially, ERs, as used by the PSC, represent the proportions of a cohort caught in various fisheries. The evaluation in this report of the CWT system focuses on the uncertainty in estimates of ERs for this reason. The third characteristic of viability requires that the uncertainty associated with CWT-based estimates does not increase management risk to unacceptable levels. Risk reflects the willingness of fishery managers to accept the consequences of error. Consequently, risk is a social manifestation of the concept of statistical uncertainty (see Chapter 0).

The SFEC (SFEC 2002) defined uncertainty surrounding estimates of ERs in terms of the mean squared error (MSE), a function of precision (variance) and accuracy (bias):

$$\text{MSE} = \text{Variance} + \text{Bias}^2$$

Variance measures the precision or error in estimates due to random variability in the estimation method, e.g., from the sampling process. This error is non-directional and the average of the error is expected to be zero. Precision is measured by estimates of variance and PSE of the estimated statistic in question. Bias is a directional error in an estimate due to not meeting one or more assumptions of the CWT program sample design. There are several potential sources of bias, such as:

- assumptions about the sample design that are not met (e.g., under- or non-sampling of fishery strata; not designing sampling programs to collect systematic data that is representative; not sampling natural escapements for CWTs in areas where CWT'd fish are present),

[3] The Expert Panel report (Hankin et.al. 2005) was focused on the problem of estimating stock-fishery-age-specific ERs.

- assumptions embedded in the methods used to estimate total mortalities are incorrect (e.g., estimating non-landed mortalities by multiplying estimates of releases by assumed release mortality rates, assuming identical encounter rates for marked and unmarked fish).

This section describes the precision currently achievable for the CWT system given the status quo (i.e., the current standards for levels of tagging and sampling) and an overview of the major factors influencing precision and bias in ER estimates.

## 5.1 Estimation of Number of Tagged Fish Harvested or Escaping

In order to discuss the factors that affect estimates of ERs, we focus on those factors affecting estimates of the number of tagged fish present in harvest or escapement, as this is the basic component of the ER. The fundamental objective of the CWT system is the estimation of the tagged fish in harvest or escapement ($R_{s,i}$) from tags ($m_{s,i}$) observed in samples, expanded for the fraction of the total harvest or escapement that is sampled ($\varphi_i$).

$$\hat{R}_{s,i} = \frac{m_{s,i}}{\varphi_i} \qquad \text{Equation 5-1}$$

where,

$\hat{R}_{s,i}$ = estimated tagged fish of cohort $s$ in total catch or escapement in stratum $i$,
$m_{s,i}$ = the number of tags from cohort $s$ observed in sample $n$ taken in stratum $i$,
$\varphi_i$ = the proportion of total catch or escapement that was sampled in stratum $i$.

The subscript $s$ represents a stock-specific cohort (brood year). The variance of the estimate of recoveries of tagged fish is a function of the number of tagged fish observed, the sample rate in the fishery or escapement stratum, and the variance of the estimated total catch or escapement that was sampled for tags (Bernard et al. 1998):

$$Var(\hat{R}_{s,i}) = \left[ \frac{m_{s,i}}{\varphi_i^2}(1-\varphi_i) + \frac{m_{s,i}^2}{\varphi_i^4} PSE^2(N_i) + \frac{m_{s,i}}{\varphi_i^2}(1-\varphi_i) PSE^2(N_i) \right] \qquad \text{Equation 5-2}$$

where,

$PSE(N_i)$ = percent standard error of the total (N) catch or escapement of stratum $i$.

When the total harvest and escapement is known without error, the variance of the estimate of tagged fish reduces to:

$$Var(\hat{R}_{s,i}) = \frac{m_{s,i}}{\varphi_i^2}(1-\varphi_i) \qquad \text{Equation 5-3}$$

## 5.2 Estimation of ERs

Estimates of tagged fish at age in harvest and escapement provide the basic information necessary for estimation of ERs. The ER for a fishery represents the proportion of the

total cohort that is killed in that fishery. The total cohort size at age $i$ for a specific stock and brood year prior to natural mortality and fisheries for that age (this includes all eventual landed and non-landed fishery mortalities, other human induced mortalities, escapements and natural mortality) may be expressed as:

$$RCohort_i = \sum_{f}^{F}\sum_{a=i}^{A}(R_{f,a} + IM_{f,a}) + \sum_{a=i}^{A}(NM_a + PSM_a + R_{e,a}) \qquad \text{Equation 5-4}$$

where,

| | |
|---|---|
| $RCohort_i$ | *Recruitment cohort size at age i* |
| $R_{f,a}$ | *Landed mortality in fishery(f) at age (a) in numbers of fish* |
| $IM_{f,a}$ | *Non-landed, fishery induced mortality in fishery(f) at age (a) in numbers of fish* |
| $NM_a$ | *Natural mortality of age (a) fish in numbers of fish* |
| $PSM_a$ | *Post fishery, pre-spawning mortality of age (a) fish (e.g., dam loss) in numbers of fish* |
| $R_{e,a}$ | *Spawning escapement of age (a) fish in numbers of fish* |
| $F$ | *Set of all fisheries affecting stock in question* |
| $A$ | *Highest age* |

Landed mortalities and spawning escapements are estimated as the number of tagged fish in the retained catch or in escapement. Non-landed fishery-related mortalities are not observable, so are estimated either from assumed relationships between the landed catch and the total number of fish encountered or from direct sampling programs to estimate the number of salmon released. Examples of non-landed mortality include fish smaller than a minimum size limit and released or fish released under mark or species retention restrictions that die during or after release. $NM_a$ in the equation above are numbers of fish and are calculated from age-specific natural mortality rates and assumed constant for the purpose of cohort run reconstruction.

The total mortality (landed catch plus incidental mortality) ER for the indicated age and fishery for a specific stock and brood year ($ER_{f,a}$) can then be estimated as:

$$ER_{f,a} = \frac{R_{f,a} + IM_{f,a}}{RCohort_a} \qquad \text{Equation 5-5}$$

where $RCohort_a$ is the cohort size at age prior to any fisheries.

The variance of the estimated ER is approximated for a specific stock and brood year by:

$$Var(ER_{f,a}) = (ER_{f,a})^2\left[\frac{Var(R_{f,s} + IM_{f,s})}{(\hat{R}_{f,s} + IM_{f,a})^2} + \frac{Var(RCohort_a)}{RCohort_a^2}\right] \qquad \text{Equation 5-6}$$

The precision of an estimated ER for fishery $f$ has two components (Equation 5-6), the variance of the tagged fish mortalities in fishery $f$ and the variance of the cohort size

estimate, which is in itself a function of the variance of tagged fish mortalities in all fisheries and escapement.

## *5.3 Explicit Consideration of Factors Affecting Uncertainty*

The principal factors that influence the uncertainty surrounding CWT-based estimates of ERs can be separated into two groups, factors affecting precision and those causing bias. In this section we focus on the following major factors affecting precision:

- number of fished tagged,
- sample rates for fisheries and escapements, and
- uncertainty in estimates of total harvest or escapement used to calculate sample expansion;

and those affecting the bias of estimates:

- sample coverage for fisheries and escapements,
- non-representative (non-systematic) sampling, and
- bias in catch or escapement estimates.

These factors are all program planning or sample design issues and the quality of ER estimates can be changed and improved through efforts to improve tagging and sampling.

The PSE used in the discussion below to represent uncertainty is a dimensionless statistic that expresses precision as a proportion of the estimated value:

$$PSE = \frac{100 * \sqrt{Variance}}{Estimated\ Value} \qquad \text{Equation 5-7}$$

The precision of the estimates of tagged fish and ERs depends on the number of tagged fish observed in the harvest or escapement ($m$), the sample rate ($\varphi$), and the precision of the estimate of the total catch or escapement being sampled ($PSE(N)$), the components of the variance shown in Equation 5-2. The number of tags observed depends on the number of tags released and the sample rate, as well as survival of the tag group and ER in the fishery. The tag group size, sample rate, and $PSE(N)$ are components of the sample design.

The estimate of tagged fish or ER become more precise with increasing number of tags observed. The average PSE for an estimate of ER of 10% is shown in Figure 5-1, where it is assumed that all fisheries are sampled at a rate of 20%, escapements at 100% and the total harvest is estimated either at a PSE(N) of 0 or 30%.. The trends in the figure are not linear, but the PSE(ER) decreases fastest as the number of tags increases from 0 to 10 tags, at which point an estimate of tagged fish ($R$) has a PSE of 30%. This level of uncertainty has been set as the maximum acceptable by at least two groups evaluating the precision of estimates of tagged fish and ERs, the Washington Joint State-Tribal Workgroup that developed the coho cohort analysis database (Marianna Alexandersdottir, pers.comm.) and the PSC CTC. Both groups set 10 observed tags per stock-specific

cohort as a minimum number required in a fishery stratum to reliably estimate ERs. A fishery stratum could be fishery and period for coho salmon and fishery-period and age for Chinook salmon. As the number of observed tags increase beyond 10 the *PSE(R)* decreases asymptotically towards zero. When *PSE(N)* is greater than zero, i.e., harvest or escapement is estimated, then the PSE(R) is limited by the precision of the total, i.e., if *PSE(N)* is 30%, the *PSE(R)* cannot be smaller than 30% (Figure 5-1)

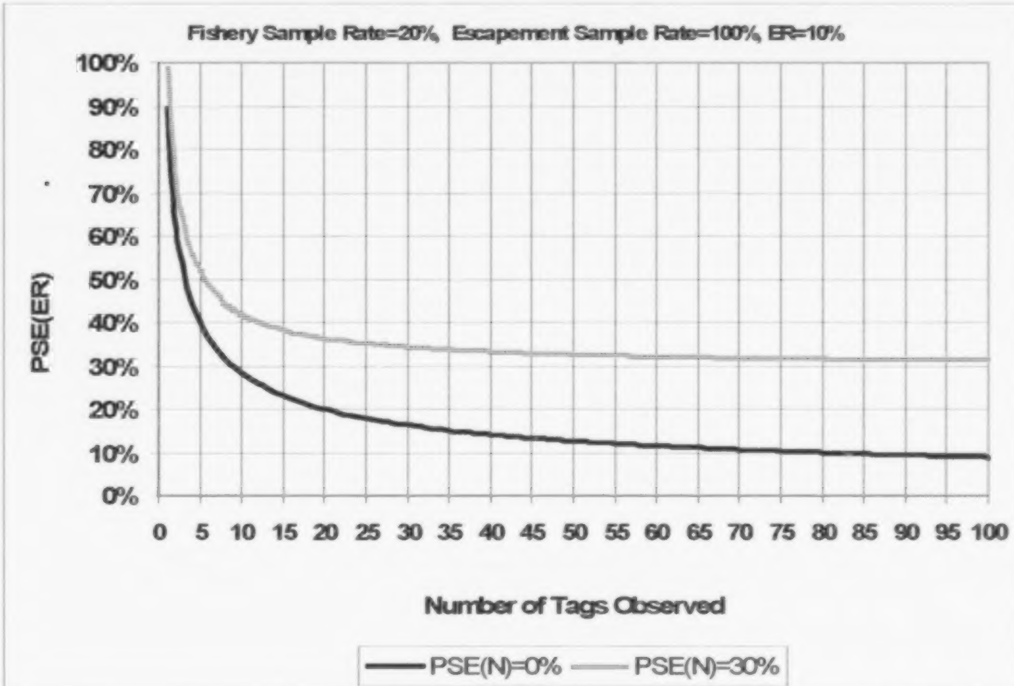


Figure 5-1. The precision (PSE) of the estimate of an ER of 10% versus the number of CWTs recovered in the fishery stratum for which the ER is being estimated, at two levels of precision for the estimate of total catch or escapement abundance (PSE(N))being sampled (0% or known without error and 30%), given a 20% sampling rate in the fishery and 100% in the escapement.

### 5.3.1 Tag Group Release Size

Increasing the tag group size will increase the number of tagged fish recruiting to fisheries and escapement and consequently, the number of tagged fish in samples to calculate fishery parameters. The PSE for the estimate of a 10% ER decreases asymptotically as the size of the tag group increases (Figure 5-2). However, the survival of the group to return also affects the precision, as shown in Figure 5-2, as fewer tagged fish return for stocks with lower survival rates, resulting in less precise estimates of ERs.

Survival to age 2 after release cannot be directly controlled through sample design, but as these tag groups are generally hatchery groups, hatchery practices can affect survivals.

Therefore, hatchery stocks with low survivals require larger releases; if survivals are very low, they may not be good candidates for use as indicator stocks.

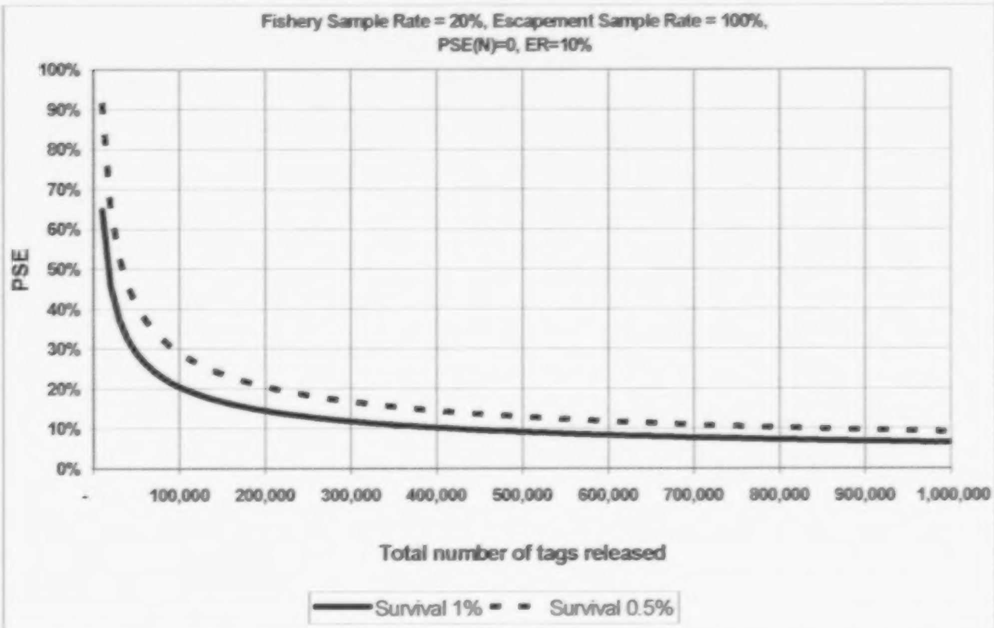


Figure 5-2. The precision (PSE) of the estimate of an ER of 10% versus the number of CWTs released at two levels of survival to age 2 (1% and 0.5%), given a 20% sampling rate in the fishery and 100% in the escapement and knowledge of the total catch abundance without error (PSE(N)=0).

### 5.3.2 Sample Rates in Fisheries

The sample rate in fisheries is an important sample design factor (see Equations 5-2 and 5-3). As sample rates increase, the number of tags used to estimate cohort size and ERs increases and the PSE for ERs decreases asymptotically (Figure 5-3). The examples illustrated in Figure 5-3 use a release group of 200,000 fish and average survival rates of 1%, which results in a cohort of 2,000 fish. Figure 5-3 shows the precision for ERs of 2.5% and 10%, assuming all total catches sampled were known and that all escapement returned to the hatchery and were sampled at 100%.

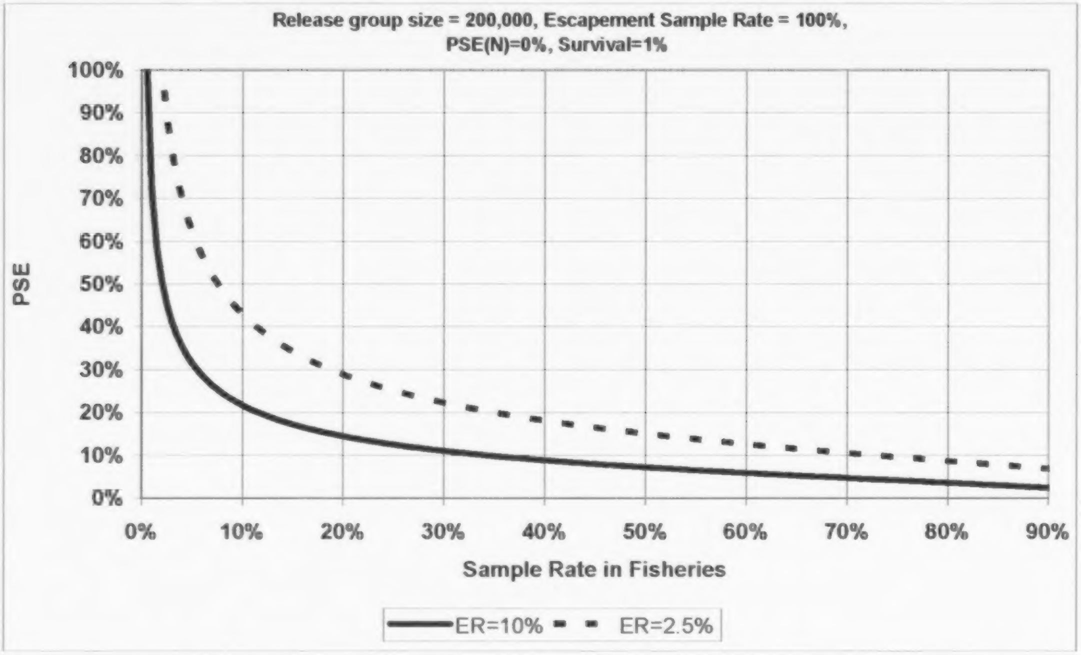


Figure 5-3. The precision (PSE) of the estimate of an ER of 10% and 2.5% for a fishery versus the sampling rate in the fishery, given a 100% sampling rate in the escapement, knowledge of the total catch abundance without error (PSE(N)=0), a CWT release group size of 200,000, and survival from release to age 2 of 1%.

### 5.3.3 Sampling Rates in Escapements

Over the last 20 years, there has been a general decrease in total ERs for many stocks and increasing rates of escapement. Consequently, recoveries of CWTs in escapements are increasingly important to determine the precision of ER estimates because the escapement represents a larger proportion of the total cohort ($RCohort_a$ in Equation 5-6).

A comparison for brood years from the late 70's, to those from the late 90's, of the total tagged return of CTC indicator stocks shows that, with the exception of the Alaskan indicator stocks, escapement represents a significantly larger proportion of the total tagged return (Figure 5-4) for the five complete brood years.

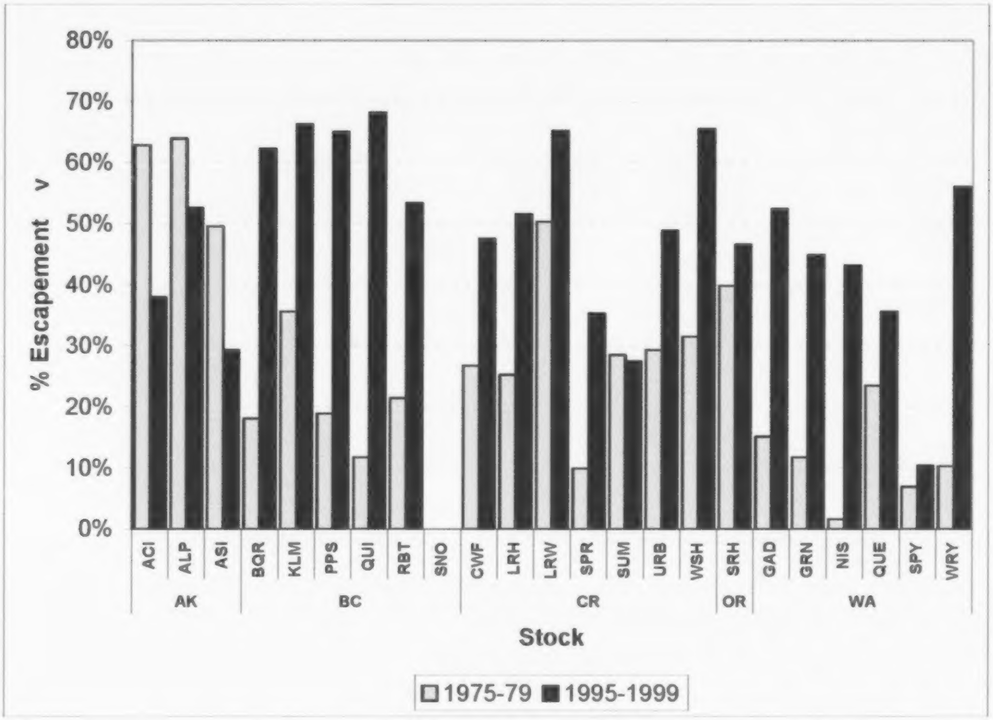


Figure 5-4. Percent of total estimated tagged fish in the escapement for early (1975-1979) and late (1995-1999) brood year periods for CTC Chinook indicator stocks. Full indicator stock names are given in Table 4.2. Data for this graph were taken from CTC Cohort Analysis System (CAS) database.

The proportion of the escapement that returns to a hatchery where it can be easily sampled and the proportion that are found on the spawning grounds are important factors affecting the precision of CWT-based estimates of ERs. The precision of the estimate of the ER depends on the proportion spawning outside the hatcheries, the sampling sample rate on natural spawning grounds where tagged fish are likely to be found, and uncertainty in estimates of total spawning escapement. If natural escapements are not sampled for CWTs, bias in estimation of ERs will be a major concern (see bias Section 5.3.5) where significant numbers of hatchery fish are on the spawning grounds.

Examination of Figure 5-5 shows the effect of spawning of tagged fish outside of the hatchery, where sampling rates are lower than in the hatchery. Given increasing total brood ER, the PSE of the total ER decreases as the ER increases, due to the increase in tags observed in the fisheries. When 100% of the escapement returns to the hatchery and is sampled at 100%, then the PSE(ER) rapidly falls to 10%. However, if all tagged fish in the escapement are in the natural spawning grounds, then the PSE(ER) does not decrease as rapidly as fewer tags are recovered in escapement (Figure 5-5).

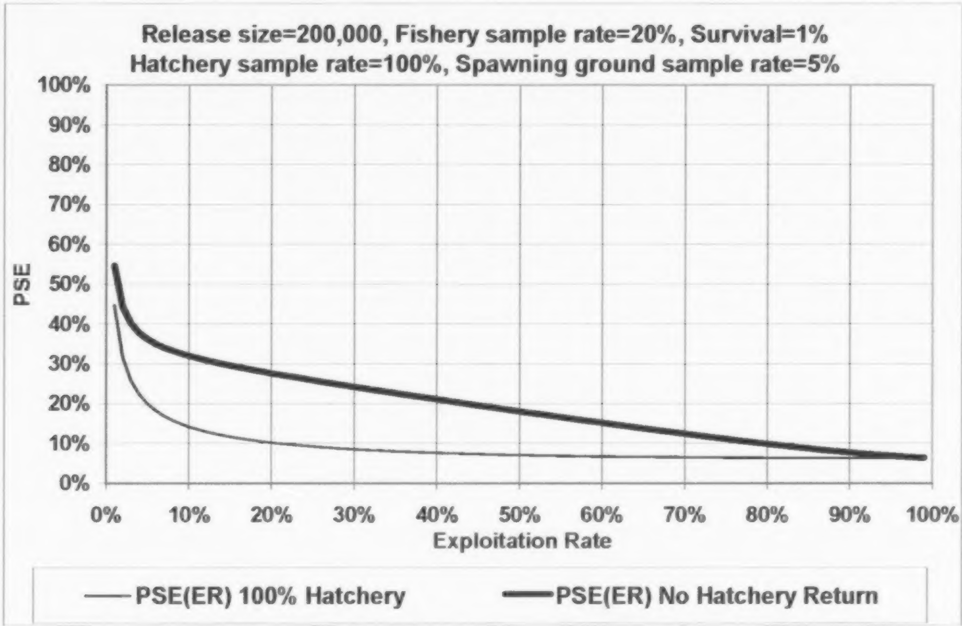


Figure 5-5. The precision (PSE) of the estimate of ER versus the magnitude of the ER estimate for the case where 100% of the escapement returns to the hatchery that has 100% sampling and the case where 100% goes to the spawning grounds that have a 5% sampling rate. A release size of 200,000 is used with survival to Age-2 of 1% and the fishery sampling rate is 20%.

### 5.3.4 Uncertainty of Total Catch and Escapement

Estimates of total catch or escapement, the number sampled, and the sample expansion are reported in the RMIS or MRP catch-sample database. However, variances of the total catch or escapement are not generally estimated or readily available for estimates of total catch or escapement. Infrequently, estimates of variance have been made to describe the uncertainty of estimates of total catch and escapement.

Commercial harvest. Commercial salmon harvest (seine, net and troll catches) are often assumed to be known (without error). In most commercial fisheries, catches are reported on fish tickets; sometimes the fish are counted and sometimes the total number of fish is estimated using total weight divided by the average weight per fish. In other fisheries, catchers are reported by fishers via paper logbooks or phone-in call centers. Whether fish catches are counted or estimated, species misidentification can introduce bias into the reported numbers. Data providing a basis for estimation of the variance of the total number of the commercially caught fish are generally unavailable

Sport harvest. Sport harvest is estimated using a variety of methods, including creel survey and catch record cards. Variances are available for some of these estimates as shown in Table 5-1 and Table 5-2.

Table 5-1 shows a summary of of the monthly coho and Chinook catch and PSEs in Southern B.C. These data are provided at the catch region level for the Strait of Georgia, Juan de Fuca, and WCVI. Note that the table does not represent total catch, as catches reported by lodges and areas with no catch estimation were excluded. The monthly catch estimates have PSEs ranging from 10-100%.

Table 5-2 shows the annual catch by area for 1998-2004 in Washington marine sport fisheries in Puget Sound with the estimated PSEs. Estimates of the Puget Sound sport catch PSE is largest for fisheries with small catches and decreases with increasing catches, ranging from 10% to 70% (Figure 5-6).

Escapement. Methods for estimating spawning escapement include direct counts (hatcheries and weirs), mark-recapture methods, and visual counts of redds or fish (e.g. area-under-the-curve and peak count expansion methods). The quality of the escapement estimates ranges similarly from known without error for counts to unknown variance and bias for stream survey methods. In B.C., Black Creek coho salmon estimates (Table 5-3) made using fence count and mark-recapture methods have PSEs ranging from 1-70% averaging 12%. The precision of the estimate of escapement for Black Creek coho salmon depends on the period the fence count can be maintained. Years when the fence is breached during a substantial portion of the migration have high PSEs. In Washington, Green River Chinook salmon mark-recapture estimates for 2000-2002 have PSEs averaging 10% (Table 5-4). For Nicola and Lower Shuswap Chinook salmon, mark-recapture spawner estimates have PSEs ranging from 3% to 12% when estimates were sex-specific (Table 5-5). An estimate of the variance of the redd count is available for 1993 for the Queets Chinook salmon escapement estimate, where an estimate of a total redd count of 1,809 had an estimated standard error of 172 and a PSE of 9.5%. Note however that a variance estimate for the expansion to total escapement is not available for the Queets Chinook salmon. Where stream surveys are used and counts are expanded to total escapement, there can be a significant opportunity for biased estimates of total escapement (Parken et al. 2002).

Table 5-1. Estimated catch and PSE by month for southern BC Chinook and coho marine sport fisheries, 2000-2005. An asterisk (*) indicates an unsurveyed period for which catch may have occurred but an estimate was not made using direct survey data. A dash indicates that a catch estimate was made from available survey data but not an estimate of variance. The catch estimates do not represent the total catch as lodge catches were excluded because catch variances have not been calculated.

| | | Georgia St. North | | | | Georgia St. South | | | | Juan de Fuca St. | | | | Alberni Canal (Area 23A) | | | | WCVI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | |
| Year | Month | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE |
| 2000 | 1 | * | * | * | * | * | * | * | * | 907 | 13 | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | * | * | * | * | 640 | 33 | 0 | -- | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | * | * | * | * | 150 | 31 | 0 | -- | * | * | * | * | * | * | * | * |
| | 4 | 187 | 49 | 0 | -- | 747 | 33 | 0 | -- | 98 | 41 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 150 | 24 | 0 | -- | 281 | 32 | 0 | -- | 638 | 42 | 14 | 149 | 0 | -- | 0 | -- | 0 | -- | 0 | -- |
| | 6 | 2,334 | 21 | 0 | -- | 671 | 23 | 58 | 75 | 2,213 | 14 | 0 | -- | 0 | -- | 0 | -- | 8,696 | 11 | 0 | -- |
| | 7 | 4,464 | 10 | 20 | 56 | 694 | 15 | 1,373 | 22 | 1,199 | 17 | 15 | 103 | 232 | 51 | 24 | 87 | 16,304 | 14 | 766 | 31 |
| | 8 | 9,025 | 11 | 64 | 70 | 890 | 14 | 1,262 | 17 | 1,531 | 18 | 224 | 41 | 14 | 79 | 455 | 24 | 4,166 | 20 | 2,872 | 20 |
| | 9 | 960 | 17 | 912 | 20 | 1,340 | 23 | 337 | 40 | 777 | 27 | 98 | 53 | 49 | 78 | 1,089 | 15 | 50 | 70 | 1,522 | 40 |
| | 10 | 89 | 33 | 74 | 43 | * | * | * | * | 344 | 28 | 263 | 40 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | 550 | 24 | 47 | 101 | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 1,746 | 24 | 0 | -- | * | * | * | * | * | * | * | * |
| 2001 | 1 | * | * | * | * | * | * | * | * | 1,097 | 19 | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | * | * | * | * | 1,171 | 35 | 0 | -- | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | * | * | * | * | 400 | 26 | 0 | -- | * | * | * | * | * | * | * | * |
| | 4 | 125 | 88 | 0 | -- | 363 | 35 | 0 | -- | 639 | 28 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 456 | 29 | 0 | -- | 697 | 21 | 14 | 88 | 486 | 28 | 0 | -- | * | * | * | * | * | * | * | * |
| | 6 | 4,340 | 31 | 0 | -- | 3,829 | 12 | 263 | 91 | 5,013 | 25 | 0 | -- | 1 | 100 | 9 | 103 | 5,516 | 19 | 1,572 | 48 |
| | 7 | 7,733 | 11 | 32 | 48 | 1,794 | 18 | 1,089 | 20 | 2,192 | 20 | 987 | 26 | 7 | 104 | 0 | -- | 12,900 | 16 | 8,150 | 12 |
| | 8 | 7,337 | 15 | 6,494 | 17 | 1,104 | 22 | 796 | 38 | 4,425 | 12 | 1,092 | 18 | 0 | -- | 555 | 14 | 8,193 | 9 | 8,905 | 11 |
| | 9 | 1,465 | 22 | 2,110 | 21 | 1,974 | 23 | 234 | 49 | 1,258 | 37 | 311 | 68 | 0 | -- | 6,707 | 13 | 3,524 | 36 | 10,861 | 25 |
| | 10 | 25 | 57 | 675 | 22 | 0 | -- | 0 | -- | 97 | 67 | 243 | 44 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | 449 | 21 | 0 | -- | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 0 | -- | 0 | -- | * | * | * | * | * | * | * | * |
| 2002 | 1 | * | * | * | * | * | * | * | * | 0 | -- | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | * | * | * | * | 0 | -- | 18 | 97 | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | * | * | * | * | 0 | -- | 0 | -- | * | * | * | * | * | * | * | * |

| | | Georgia St. North | | | | Georgia St. South | | | | Juan de Fuca St. | | | | Alberni Canal (Area 23A) | | | | WCVI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | |
| Year | Month | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE |
| | 4 | 359 | 26 | 0 | -- | 1,346 | 60 | 0 | -- | 638 | 56 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 2,961 | 21 | 0 | -- | 2,505 | 23 | 0 | -- | 641 | 28 | 0 | -- | * | * | * | * | * | * | * | * |
| | 6 | 14,205 | 27 | 18 | 122 | 1,522 | 24 | 33 | 69 | 4,556 | 25 | 0 | -- | 71 | 68 | 0 | -- | 4,409 | 13 | 297 | 25 |
| | 7 | 13,144 | 10 | 0 | -- | 1,004 | 19 | 1,185 | 26 | 4,518 | 14 | 100 | 53 | 108 | 62 | 0 | -- | 11,266 | 10 | 3,171 | 14 |
| | 8 | 11,079 | 16 | 1,343 | 67 | 1,707 | 18 | 169 | 45 | 4,509 | 24 | 1,106 | 24 | 7,918 | 7 | 692 | 29 | 14,912 | 12 | 11,808 | 13 |
| | 9 | 1,920 | 35 | 1,183 | 43 | 983 | 32 | 114 | 76 | 822 | 65 | 3,010 | 20 | 5,806 | 26 | 5,048 | 21 | 799 | 31 | 723 | 27 |
| | 10 | 59 | 18 | 522 | 55 | 43 | 40 | 15 | 83 | 119 | 79 | 527 | 42 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | 0 | -- | 0 | -- | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 0 | -- | 0 | -- | * | * | * | * | * | * | * | * |
| 2003 | 1 | * | * | * | * | * | * | * | * | 1,118 | 29 | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | * | * | * | * | 138 | 45 | 0 | -- | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | * | * | * | * | 342 | 27 | 0 | -- | * | * | * | * | * | * | * | * |
| | 4 | 217 | 30 | 0 | -- | 493 | 26 | 0 | -- | 1,323 | 17 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 1,969 | 19 | 0 | -- | 746 | 19 | 18 | 114 | 664 | 28 | 0 | -- | * | * | * | * | * | * | * | * |
| | 6 | 4,186 | 12 | 4 | 109 | 1,095 | 22 | 387 | 51 | 4,129 | 13 | 195 | 47 | 22 | -- | 0 | -- | 2,439 | 12 | 477 | 21 |
| | 7 | 3,579 | 14 | 64 | 72 | 1,140 | 19 | 5,365 | 15 | 6,187 | 11 | 4,786 | 11 | 52 | -- | 83 | -- | 16,156 | 10 | 14,619 | 7 |
| | 8 | 3,555 | 11 | 129 | 19 | 1,342 | 17 | 1,464 | 25 | 10,046 | 8 | 2,502 | 14 | 9,918 | -- | 1,150 | -- | 28,319 | 6 | 19,124 | 7 |
| | 9 | 521 | 21 | 762 | 15 | 1,433 | 33 | 72 | 32 | 2,657 | 8 | 3,923 | 7 | 2,994 | -- | 8,803 | -- | 4,816 | 20 | 8,620 | 18 |
| | 10 | 14 | 59 | 22 | 105 | 140 | 60 | 6 | 168 | 106 | 67 | 429 | 57 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | 385 | 55 | 0 | -- | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 496 | 26 | 0 | -- | * | * | * | * | * | * | * | * |
| 2004 | 1 | * | * | * | * | * | * | * | * | 2,039 | 31 | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | * | * | * | * | 785 | 21 | 0 | -- | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | * | * | * | * | 619 | 33 | 0 | -- | * | * | * | * | * | * | * | * |
| | 4 | * | * | * | * | 54 | 72 | 0 | -- | 275 | 25 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 238 | 33 | 0 | -- | 263 | 30 | 0 | -- | 676 | 19 | 0 | -- | * | * | * | * | * | * | * | * |
| | 6 | 1,388 | 14 | 0 | -- | 143 | 32 | 0 | -- | 4,553 | 17 | 164 | 51 | 0 | -- | 0 | -- | 4,519 | 10 | 494 | 18 |
| | 7 | 1,957 | 17 | 15 | 110 | 453 | 24 | 584 | 23 | 9,649 | 11 | 1,249 | 18 | 82 | -- | 6 | -- | 21,778 | 8 | 12,029 | 9 |
| | 8 | 4,963 | 12 | 386 | 39 | 729 | 33 | 800 | 24 | 13,201 | 7 | 3,367 | 13 | 4,443 | -- | 512 | -- | 42,648 | 6 | 17,690 | 8 |
| | 9 | 1,481 | 20 | 951 | 23 | 1,434 | 26 | 123 | 53 | 4,194 | 12 | 4,994 | 10 | 4,007 | -- | 623 | -- | 10,896 | 12 | 5,020 | 23 |
| | 10 | 53 | 50 | 83 | 44 | 693 | 44 | 135 | 57 | 2,153 | 25 | 1,265 | 24 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | 992 | 35 | 0 | -- | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 1,532 | 14 | 0 | -- | * | * | * | * | * | * | * | * |

| | | Georgia St. North | | | | Georgia St. South | | | | Juan de Fuca St. | | | | Alberni Canal (Area 23A) | | | | WCVI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | | Chinook | | Coho | |
| Year | Month | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE | Catch | PSE |
| 2005 | 1 | * | * | * | * | 0 | -- | 0 | -- | 1,640 | 15 | 0 | -- | * | * | * | * | * | * | * | * |
| | 2 | * | * | * | * | 2 | 110 | 0 | -- | 499 | 28 | 3 | 104 | * | * | * | * | * | * | * | * |
| | 3 | * | * | * | * | 49 | 77 | 0 | -- | 379 | 19 | 0 | -- | * | * | * | * | * | * | * | * |
| | 4 | * | * | * | * | 46 | 70 | 0 | -- | 141 | 28 | 0 | -- | * | * | * | * | * | * | * | * |
| | 5 | 772 | 40 | 0 | -- | 235 | 27 | 0 | -- | 492 | 44 | 0 | -- | * | * | * | * | * | * | * | * |
| | 6 | 1,178 | 21 | 0 | -- | 117 | 59 | 4 | 44 | 2,475 | 25 | 453 | 38 | 6 | -- | 0 | -- | 5,516 | 10 | 1,646 | 17 |
| | 7 | 3,057 | 25 | 332 | 70 | 314 | 22 | 238 | 54 | 5,903 | 11 | 2,127 | 16 | 19 | -- | 6 | -- | 17,761 | 7 | 10,686 | 7 |
| | 8 | 3,126 | 23 | 146 | 71 | 209 | 29 | 301 | 31 | 12,039 | 16 | 946 | 27 | 7,342 | -- | 338 | -- | 37,309 | 8 | 18,717 | 12 |
| | 9 | 2,213 | 22 | 184 | 39 | 858 | 23 | 140 | 43 | 5,585 | 19 | 2,192 | 18 | 2,287 | -- | 849 | -- | 10,110 | 11 | 6,309 | 12 |
| | 10 | * | * | 47 | 48 | 76 | 59 | 19 | 91 | 75 | 42 | 1,870 | 10 | * | * | * | * | * | * | * | * |
| | 11 | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| | 12 | * | * | * | * | * | * | * | * | 1,250 | 39 | 0 | -- | * | * | * | * | * | * | * | * |

Table 5-2. Estimated average monthly sport harvest and total sport harvest for years 1998-2004 for Washington Puget Sound marine areas 5-13. The percent standard error (PSE) is also averaged over all the months within years. Estimates are derived using Washington catch record cards and creel surveys.

| | | Chinook | | Coho | |
|---|---|---|---|---|---|
| Area | Year | Catch | PSE | Catch | PSE |
| 5 | 1998 | 125 | 46% | 4,763 | 12% |
| | 1999 | 67 | 67% | 1,121 | 22% |
| | 2000 | 47 | 60% | 2,650 | 12% |
| | 2001 | 506 | 16% | 19,665 | 6% |
| | 2002 | 432 | 29% | 12,839 | 5% |
| | 2003 | 549 | 34% | 11,989 | 5% |
| | 2004 | 458 | 40% | 9,147 | 15% |
| 6 | 1998 | 121 | 54% | 757 | 44% |
| | 1999 | 160 | 60% | 161 | 28% |
| | 2000 | 212 | 20% | 500 | 24% |
| | 2001 | 105 | 30% | 740 | 18% |
| | 2002 | 51 | 49% | 343 | 24% |
| | 2003 | 237 | 33% | 658 | 13% |
| | 2004 | 104 | 48% | 348 | 39% |
| 7 | 1998 | 341 | 34% | 622 | 34% |
| | 1999 | 339 | 36% | 123 | 57% |
| | 2000 | 404 | 32% | 881 | 13% |
| | 2001 | 727 | 15% | 980 | 23% |
| | 2002 | 536 | 17% | 1,105 | 8% |
| | 2003 | 372 | 19% | 486 | 17% |
| | 2004 | 280 | 28% | 368 | 37% |
| 8-1 | 1998 | 72 | 62% | 216 | 66% |
| | 1999 | 76 | 68% | 222 | 45% |
| | 2000 | 161 | 45% | 280 | 55% |
| | 2001 | 122 | 46% | 822 | 17% |
| | 2002 | 82 | 28% | 215 | 27% |
| | 2003 | 61 | 51% | 293 | 23% |
| | 2004 | 83 | 31% | 162 | 29% |
| 8-2 | 1998 | 55 | 71% | 786 | 35% |
| | 1999 | 124 | 47% | 535 | 27% |
| | 2000 | 313 | 47% | 2,358 | 14% |
| | 2001 | 373 | 17% | 3,142 | 32% |
| | 2002 | 223 | 25% | 1,244 | 20% |
| | 2003 | 380 | 13% | 1,699 | 17% |
| | 2004 | 196 | 40% | 768 | 34% |
| 9 | 1998 | 208 | 48% | 1,600 | 29% |
| | 1999 | 351 | 44% | 828 | 44% |
| | 2000 | 334 | 36% | 824 | 49% |
| | 2001 | 519 | 23% | 10,326 | 8% |
| | 2002 | 213 | 25% | 1,118 | 34% |
| | 2003 | 152 | 24% | 3,831 | 12% |
| | 2004 | 206 | 36% | 1,826 | 23% |
| 10 | 1998 | 205 | 37% | 780 | 34% |
| | 1999 | 147 | 53% | 174 | 62% |
| | 2000 | 269 | 39% | 710 | 37% |
| | 2001 | 386 | 24% | 2,597 | 27% |
| | 2002 | 496 | 18% | 1,012 | 21% |

| Area | Year | Chinook | | Coho | |
|---|---|---|---|---|---|
| | | Catch | PSE | Catch | PSE |
| | 2003 | 575 | 15% | 1,706 | 21% |
| | 2004 | 516 | 25% | 1,564 | 17% |
| 11 | 1998 | 352 | 28% | 311 | 36% |
| | 1999 | 721 | 26% | 99 | 58% |
| | 2000 | 369 | 25% | 336 | 30% |
| | 2001 | 1,278 | 14% | 1,385 | 22% |
| | 2002 | 975 | 17% | 306 | 26% |
| | 2003 | 440 | 14% | 683 | 29% |
| | 2004 | 820 | 19% | 975 | 23% |
| 12 | 1998 | 29 | 63% | 254 | 50% |
| | 1999 | 129 | 41% | 39 | 55% |
| | 2000 | 179 | 36% | 195 | 37% |
| | 2001 | 74 | 46% | 1,100 | 32% |
| | 2002 | 169 | 25% | 575 | 22% |
| | 2003 | 205 | 34% | 717 | 16% |
| | 2004 | 324 | 29% | 989 | 13% |
| 13 | 1998 | 203 | 47% | 95 | 48% |
| | 1999 | 285 | 56% | 55 | 63% |
| | 2000 | 150 | 39% | 221 | 40% |
| | 2001 | 256 | 31% | 269 | 19% |
| | 2002 | 212 | 29% | 96 | 34% |
| | 2003 | 184 | 42% | 212 | 32% |
| | 2004 | 129 | 38% | 177 | 33% |

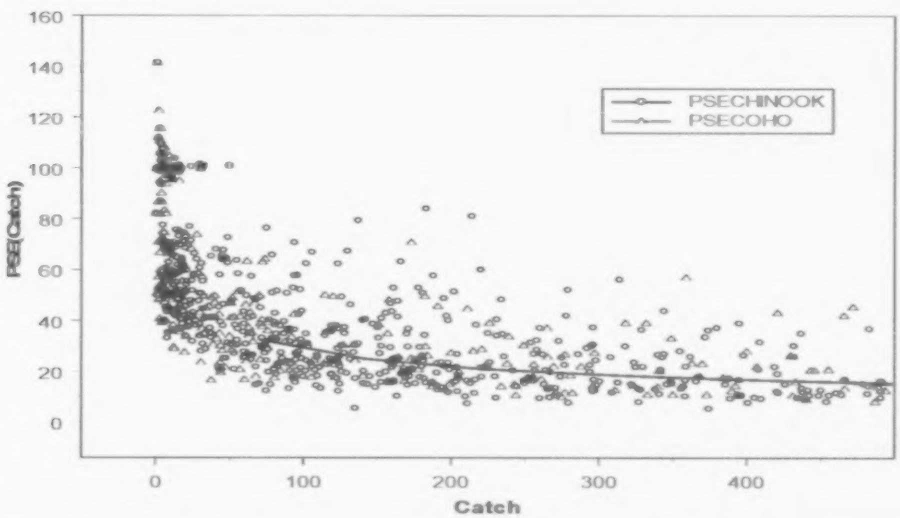


Figure 5-6. Relationship between PSE and total catch for Washington Puget Sound sport fisheries from 1998-2004.

Table 5-3. Black Creek coho salmon escapement and measurements of uncertainty (variance and PSE).

| Return Year | Escapement | Variance | PSE |
|---|---|---|---|
| 1984 | 5,990 | NA | NA |
| 1985 | 5,992 | 524,555 | 12% |
| 1986 | 4,818 | 53,051 | 5% |
| 1987 | 785 | 1,256 | 5% |
| 1988 | 3,122 | 46,898 | 7% |
| 1989 | 3,272 | 19,496 | 4% |
| 1990 | 1,237 | 38,861 | 16% |
| 1991 | 3,568 | 10,068 | 3% |
| 1992 | 1,720 | 536 | 1% |
| 1993 | 959 | 395 | 2% |
| 1994 | 900 | 25,260 | 18% |
| 1995 | 1,760 | 11,003 | 6% |
| 1996 | 284 | 5,112 | 25% |
| 1997 | 1,200 | 184,624 | 36% |
| 1998 | 7,616 | 1,398,779 | 16% |
| 1999 | 511 | 2,077 | 9% |
| 2000 | 1,114 | 613,843 | 70% |
| 2001 | 12,100 | 579,079 | 6% |
| 2002 | 4,322 | 2,858 | 1% |
| 2003 | 2,780 | 33,707 | 7% |
| 2004 | 4,065 | 15,664 | 3% |
| 2005 | 2,248 | 28,419 | 7% |

Table 5-4. Green River Chinook salmon escapement and a measurement of uncertainty (PSE).

| Year | Escapement Age 3 and older | PSE |
|---|---|---|
| 2000 | 10,525 | 14% |
| 2001 | 21,402 | 7% |
| 2002 | 15,263 | 9% |

Table 5-5. Nicola and Lower Shuswap River Chinook salmon escapements (age 3 and older) and measurements of uncertainty (PSE).

| Year | Females | | Males | |
|---|---|---|---|---|
| | Escapement | PSE | Escapement | PSE |
| | | Nicola River | | |
| 2000 | 4,768 | 5% | 3,415 | 7% |
| 2001 | 5,522 | 5% | 3,462 | 6% |
| 2002 | 12,885[1] | 4%[1] | NA[1] | NA[1] |
| 2003 | 8,619 | 4% | 5,871 | 4% |
| 2004 | 6,221 | 8% | 3,931 | 9% |
| 2005 | 1,732 | 9% | 1,506 | 12% |
| 2006 | 2,985 | 7% | 2,102 | 10% |
| | | Lower Shuswap River | | |
| 2004 | 9,071 | 6% | 7,892 | 6% |
| 2005 | 8,726 | 4% | 9,167 | 5% |
| 2006 | 36,796 | 3% | 22,288 | 3% |

[1] Escapement reported for both sexes combined at Nicola River in 2002.

### 5.3.5 Bias

Bias is non-random error which is generally caused by violation of the assumptions of the estimation model and/or sample design. For instance, in the estimation of total ERs, the following assumptions are made:

1. all fisheries and escapement for a tagged stock are sampled for tags,
2. an unbiased estimate of all catch and escapement exist,
3. all tagged fish in a sample are located and processed, and
4. sampling in each stratum is representative, i.e., all tag codes are present in the samples in the same proportion as they are present in the total catch or escapement for the stratum.

Violation of any of these assumptions will lead to biased estimates of ERs; that is, they will be either under-estimated or over-estimated. For example, Table 5-1 shows that Canadian sport fishery catches were not estimated during all months by the creel survey program. CWTs were submitted voluntarily by anglers during months when there was no creel survey program. For those tags, head submission rates estimated during the months with creel surveys were used to expand observed tags to estimated recoveries. This approach leads to bias in the estimated tag recoveries, but these estimates are believed to be less biased than if the observed tags were not expanded (i.e. an assumed submission rate of 100%). Generally, the precision of estimates of ERs can be estimated but bias cannot be. Bias may be minimized through planning and adherence to the sample design of the CWT program and may be studied through research programs.

### 5.3.6 Summary

Often catch in commercial fisheries is assumed to be known without error, but the assumption is untested. In reality, errors exist with commercial catch data and depend, in part, on how the

catch is estimated and reported on the fish tickets. Catch in sport fisheries is always estimated, increasing the variance and PSE of the estimate of ER. Over the period from the late 1970's to the present, the proportion of total fishery exploitation on Chinook and coho in commercial fisheries vs. sport fisheries have decreased (Figure 5-7). Since sport harvest is estimated with higher uncertainty than commercial harvest, the recent estimates of total ER are relatively more uncertain than the estimates of total ER were in the late 1970's. However, there were some exceptions. For instance, the Lower Columbia River Wild, Green River, and Nisqually River Chinook stocks (LRW, GRN and NIS in Figure 5-7) exhibit a larger proportion of the harvest in sport fisheries in the earlier period. Increasing PSE may not be simply a result of this increase in the sport proportion of the total exploitation, but also may be due to reductions in total catch.

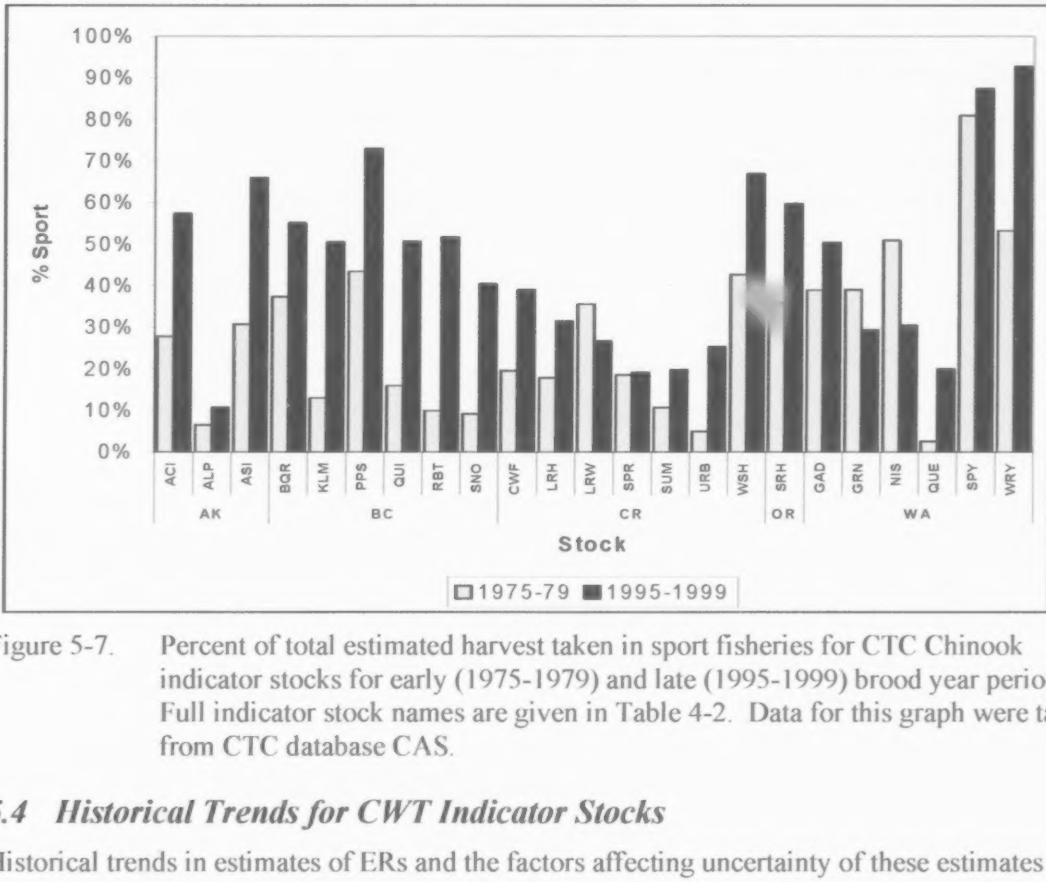


Figure 5-7. Percent of total estimated harvest taken in sport fisheries for CTC Chinook indicator stocks for early (1975-1979) and late (1995-1999) brood year periods. Full indicator stock names are given in Table 4-2. Data for this graph were taken from CTC database CAS.

## *5.4 Historical Trends for CWT Indicator Stocks*

Historical trends in estimates of ERs and the factors affecting uncertainty of these estimates can be evaluated in more detail by examining selected CWT'd Chinook ER indicator stocks and coho stocks used as natural stock representatives. Green River fall Chinook (Puget Sound), Taku River wild coho (Southeast Alaska), Black Creek coho (East Coast Vancouver Island), and Queets River coho (Washington coastal) are examples selected to demonstrate CWT program performance reflecting differences in the species, region, fisheries involved, and the primary agency responsible for design, tagging and sampling.

### 5.4.1 Green River Fall Chinook Salmon

Green River fall Chinook salmon are released from Soos Creek Hatchery on the Green River in Puget Sound. This stock is a representative of central Puget Sound fall Chinook salmon.

#### *5.4.1.1 Releases*

With a few exceptions, approximately 200 K fingerlings per tag group have been released for this stock since 1971 (Figure 5-8). Since 1996, a double index tag (DIT) group has been released annually from Soos Creek Hatchery, with a total of approximately 200 thousand marked and 200 thousand unmarked tagged fingerlings released annually.

#### *5.4.1.2 Total Return from Release*

The percent of the total release that is estimated to return to fisheries and escapement (survival index) has decreased from 1.5% in the 1970's to approximately 0.5% for the more recent complete brood years (Figure 5-9).

For the last 5 complete brood years (1995-1999), the majority of the fishery recoveries for Green River stock are taken in the terminal net fisheries, other Puget Sound net and sport fisheries, and WCVI fisheries (Table 5-6) and about 35% of the total return was recovered in escapement, the hatchery or on the spawning grounds.

The Green River stock returns to escapement in the hatchery and to spawning grounds, but the spawning grounds have only been sampled consistently since the late 1980's. Prior to brood year 1985, escapement sampling included only hatchery returns. Since brood year 1985, on average, only 55-75% of the estimated escapement to the Green River has been to the hatchery (Figure 5-10).

Since 1985, the first brood year sampling included spawning ground returns, an decreasing percentage of the total tags recovered or estimated has been taken in troll fisheries, while a larger percentage has been taken in net fisheries and returned to escapement (Figure 5-11).

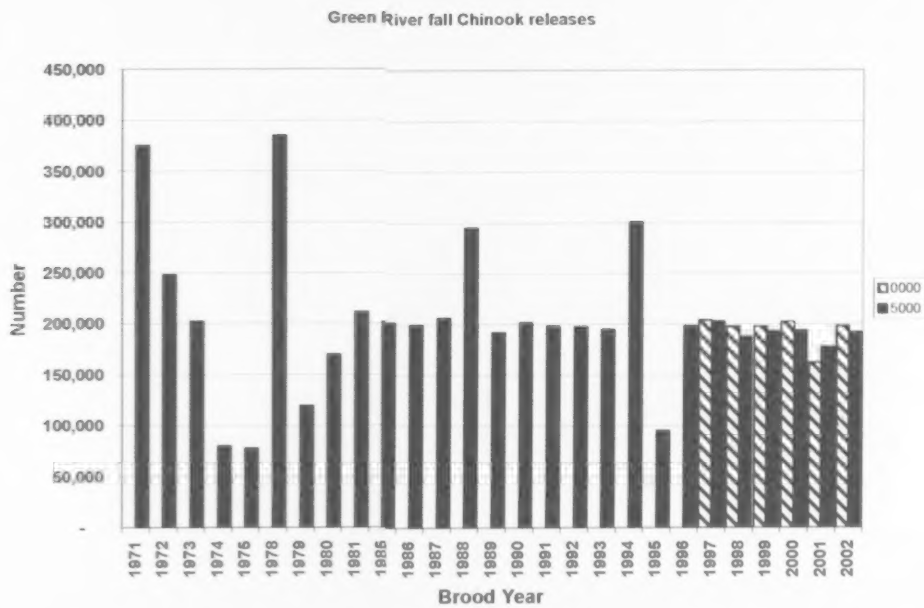


Figure 5-8. Releases of tagged Green River fall Chinook salmon from the Soos Creek Hatchery for brood years 1971-2002. (In the legend, 0000 indicates unmarked fish and 5000, adipose fin clipped).

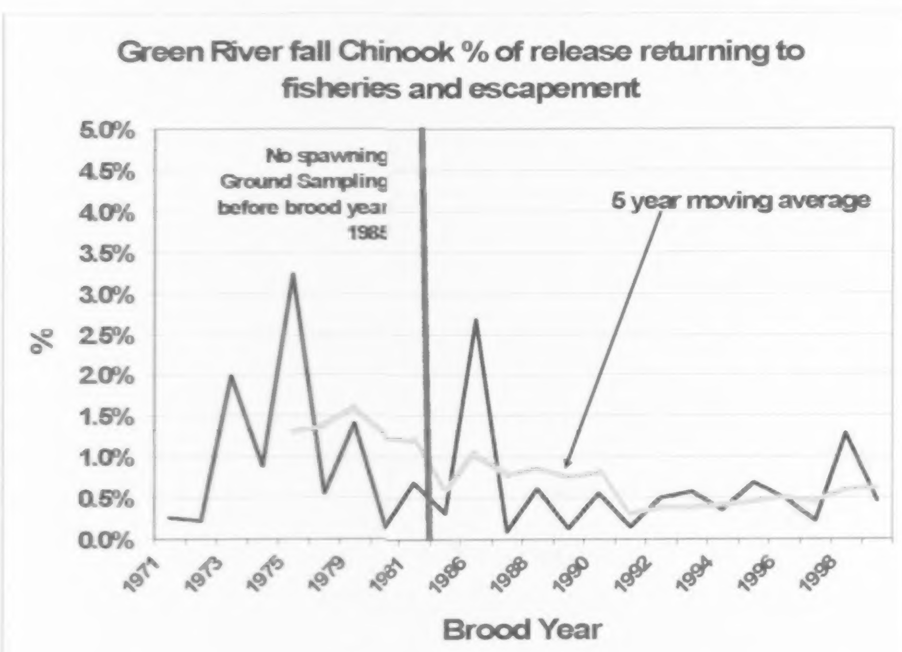


Figure 5-9. Percent of total releases returning to fisheries and escapement for Green River Chinook salmon brood 1971-1999. Note that prior to 1985 brood there was no spawning ground sampling.

Table 5-6. Number of estimated tagged Green River Chinook salmon returning to escapement and fisheries averaged over brood years 1995-1999. Fishery definitions are based on those used by CTC for the ER analysis.

| | Age 2 | Age 3 | Age 4 | Age 5 | Total |
|---|---|---|---|---|---|
| Escapement | 12 | 143 | 145 | 12 | 312 |
| Terminal net | 2 | 63 | 151 | 15 | 231 |
| WCVI troll | - | 12 | 59 | 4 | 75 |
| Puget Sound South sport | 3 | 28 | 35 | 3 | 69 |
| Puget Sound South net | - | 21 | 38 | 5 | 64 |
| WCVI sport | - | 15 | 21 | - | 36 |
| Georgia Strait net | 1 | 21 | 14 | - | 35 |
| WA/OR troll | - | 9 | 21 | 3 | 32 |
| Puget Sound north sport | - | 1 | 10 | - | 12 |
| NBC troll | - | - | 2 | 2 | 5 |
| Alaska troll | - | 1 | 6 | 1 | 8 |
| North central BC sport | - | 2 | 2 | - | 4 |
| WA coastal sport | - | 2 | 1 | - | 3 |
| Terminal sport | 1 | - | - | - | 1 |
| Alaska net | 0 | 0 | - | - | 0 |

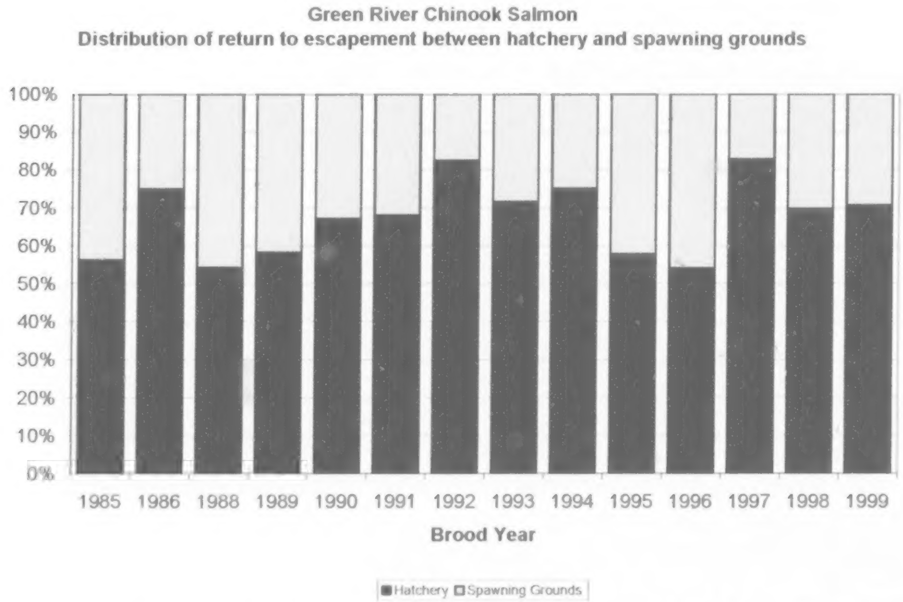


Figure 5-10. Percent of total tagged escapement returning to hatchery or spawning grounds for Green River fall Chinook brood years 1985-1999, 1987 not included.

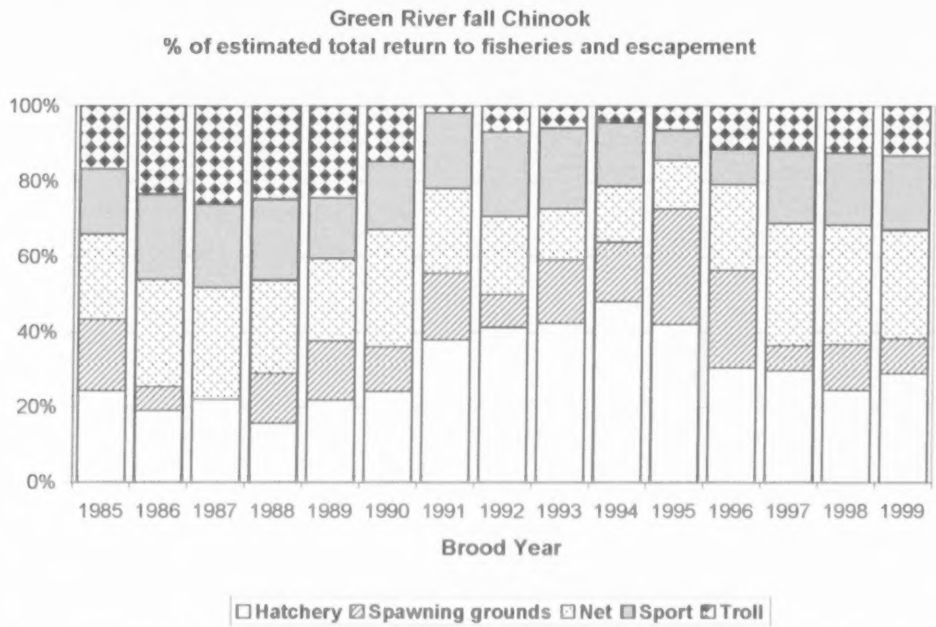


Figure 5-11. Percent of total return by location for tagged Green River Chinook brood years 1985-1999 (since commencement of spawning ground sampling).

### *5.4.1.3 Sampling in Fisheries and Escapement*

An examination of the number of tagged fish recovered in fisheries and escapement shows that there is a general decrease in the number of tagged fish observed in samples (Figure 5-12), with the exception of hatchery recoveries and net recoveries. A comparison of the distribution of tag recoveries between pre-terminal and terminal fisheries and escapement for two periods, 1975-1979 and 1995-1999 (last 5 complete brood years) shows that there has been a change in both the pattern of tag recoveries and fisheries (Table 5-7). Tagged fish were recovered in net fisheries in both pre-terminal and terminal areas in the early period, but for the last 5 broods only terminal net fisheries are exploiting Green River tagged Chinook salmon. These terminal net fisheries do not show a decrease in the number of tagged fish exploited or recovered from the earlier to the later period (Table 5-7). For troll and sport fisheries there is a significant decrease in the number of fish estimated to have been harvested and in the number of tagged fish recovered in samples and in the precision of the estimate of the number of tagged fish harvested as measured by the percent standard error (Table 5-7).

Table 5-7 shows that since the early period of 1975-1979 pre-terminal troll and sport fisheries have decreased in size and the number of tags recovered has decreased, but the terminal net fishery has maintained in size and in the number of tags recovered.

### *5.4.1.4 ERs*

The Green River total ERs have decreased from approximately 50% for brood years in the 1970's and 1980's to 30-40% in the late 1990's, and this decline has occurred in the pre-terminal fisheries (Figure 5-13). Comparison of the two periods used above (early and last 5 complete

broods) shows that as with tag recoveries in Table 5-7, the decrease in annual ERs has occurred in pre-terminal fisheries while terminal fisheries have maintained similar ERs for both periods (Table 5-8). For these comparisons total escapement was adjusted in the early period to include an estimate of strays to the spawning grounds.

*5.4.1.5 Conclusion*

Estimates of PSE for estimates of the number of recoveries in pre-terminal and terminal area fisheries are presented in Table 5-7, for the earlier period (1975-1979 brood years) and a more recent period (1995-1999 brood years) for the Green River Chinook stock. PSE estimates are provided for recoveries on spawning grounds, however no estimates are available for the earlier period. PSE estimates generally are higher for recoveries in fisheries in the more recent period and may be explained by lower numbers of tagged fish in pre-terminal sport and troll fisheries. Pre-terminal fishing levels were reduced in both Canada and the southern United States for conservation purposes.

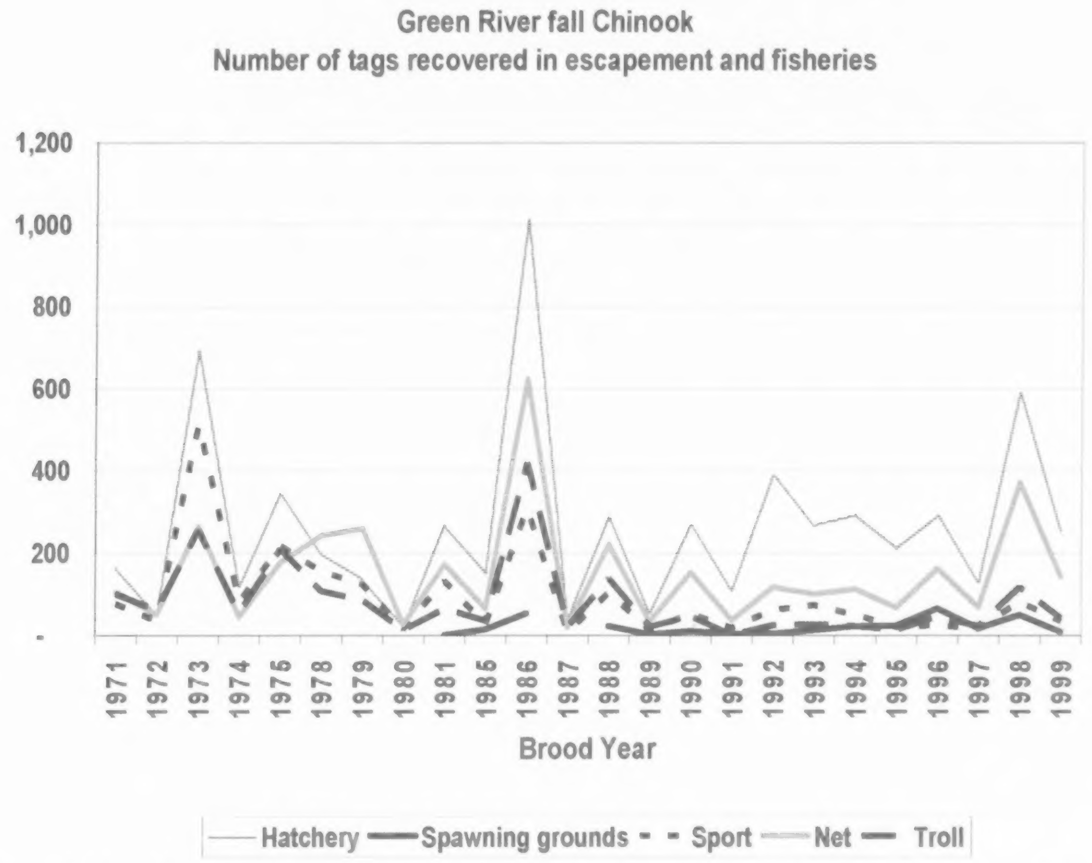


Figure 5-12. Number of observed recoveries for Green River Chinook salmon in sport, troll and net fisheries.

Table 5-7. Number of tagged Green River Chinook salmon recovered in samples, estimated number, % in samples and PSE for pre-terminal and terminal fisheries summarized for early years (1975, 1978 and 1979) available and for last five complete brood years.

| | | 1975-1979 | | 1995-1999 | |
|---|---|---|---|---|---|
| | | Pre-terminal | Terminal | Pre-terminal | Terminal |
| Hatchery | Observed in sample | | 225 | | 295 |
| | Estimated | | 249 | | 312 |
| | % in sample | | 90.5% | | 94.4% |
| | PSE | | 8.6% | | 7.9% |
| Spawning grounds | Observed in sample | | | | 33 |
| | Estimated | | No | | 172 |
| | % in sample | | Sampling | | 19.3% |
| | PSE | | | | 36.5% |
| Sport | Observed in sample | 142 | 24 | 24 | 12 |
| | Estimated | 617 | 110 | 137 | 38 |
| | % in sample | 23.0% | 21.4% | 17.2% | 33.0% |
| | PSE | 12.4% | 25.8% | 34.0% | 49.3% |
| Net | Observed in sample | 60 | 167 | | 162 |
| | Estimated | 198 | 315 | | 295 |
| | % in sample | 30.5% | 53.0% | | 55.1% |
| | PSE | 20.1% | 11.7% | | 11.9% |
| Troll | Observed in sample | 135 | | 49 | |
| | Estimated | 625 | | 124 | |
| | % in sample | 21.6% | | 39.2% | |
| | PSE | 13.4% | | 24.3% | |

Table 5-8. Estimated annual ERs for Green River Chinook salmon for pre-terminal and terminal fisheries for two periods (early and last 5 complete brood years). Escapement has been adjusted for early years to include spawning ground returns of tagged fish (using average stray rate of broods 1985-1999).

| | Pre-terminal | | | | Terminal | | | |
|---|---|---|---|---|---|---|---|---|
| | 1975,78 and 79 | | 1995-1999 | | 1975,78 and 79 | | 1995-1999 | |
| | ER | PSE | ER | PSE | ER | PSE | ER | PSE |
| Age 2 | 4.5% | 27.4% | 1.6% | 53.3% | 1.4% | 28.0% | 0.3% | 70.0% |
| Age 3 | 24.8% | 13.7% | 5.1% | 31.1% | 5.8% | 17.1% | 5.6% | 13.3% |
| Age 4 | 44.9% | 11.2% | 23.3% | 19.4% | 21.7% | 14.9% | 21.2% | 12.9% |

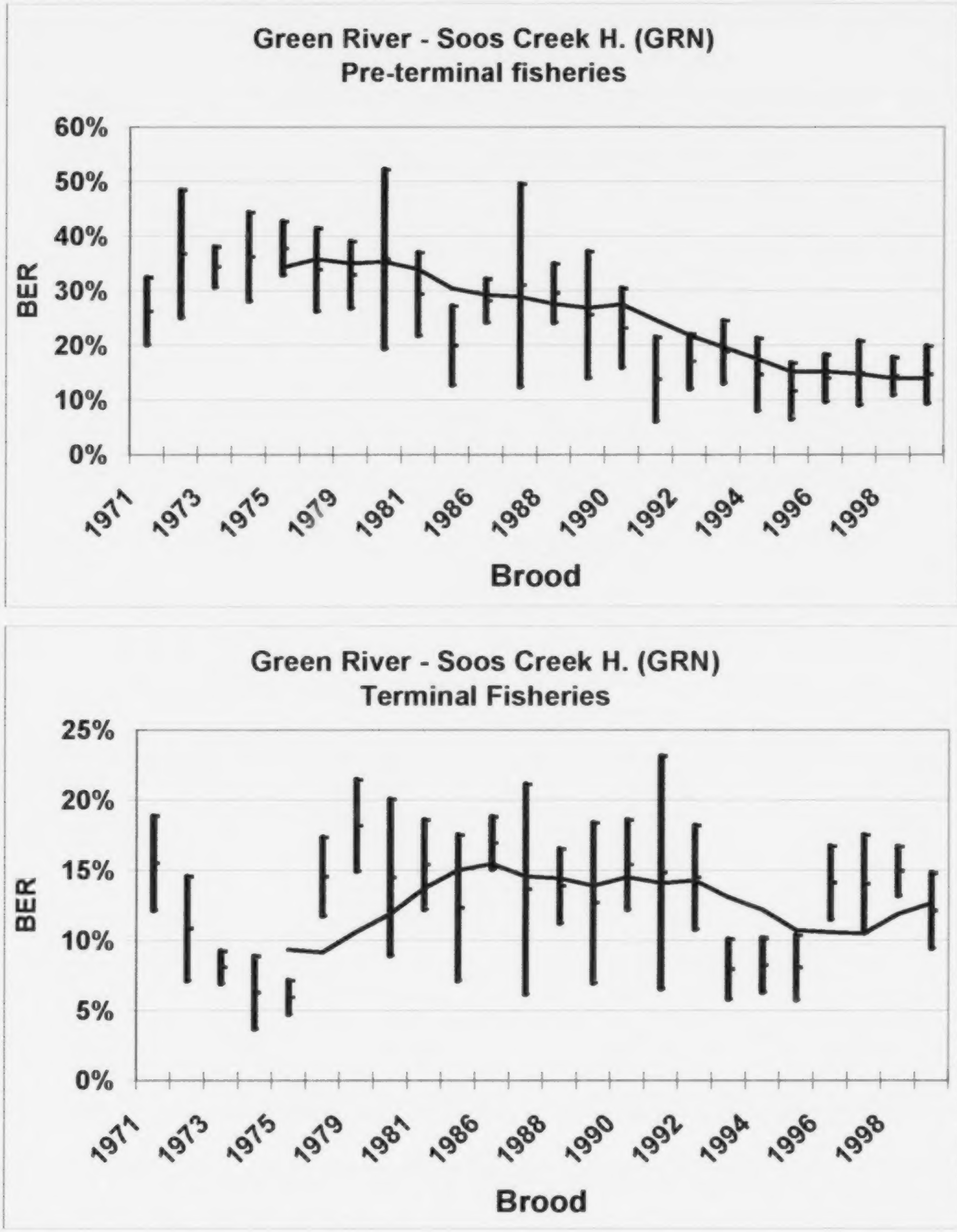


Figure 5-13. Estimates of brood ERs (ER) for Green River fall Chinook salmon for brood years 1971-1999 for pre-terminal and terminal fisheries, with 5-year average trend lines. Note that prior to the 1985 brood year spawning ground returns were not sampled but the escapement was adjusted using information from later years.

### 5.4.2 Taku River Wild Coho Salmon

Taku River coho salmon are trapped and tagged during the outmigration each spring by a joint (Alaska and Canada) crew in the lower river. The marked fraction with CWTs, and estimation of the number of smolts, is determined the following year by sampling done in the inriver escapement program. This stock is a large wild stock, smolts are age 2 or 3 and adults are age 3 or 4; almost all adults return after 1 year of ocean residence. The terminal run is jointly managed by Alaska and Canada under the transboundary river annex of the PST. Alaska Department of Fish and Game (ADFG) and Canadian Department of Fisheries and Oceans (CDFO) use stock assessment for inseason management of escapement, with run strength judged by inriver abundance and marine-fishery CWT recoveries expanded to total estimated harvest, for run reconstruction. Population statistics are estimated postseason and reported in ADFG technical reports and are available since 1992 (e.g., Jones et al. 2006; Table 5-9). Marine harvests are estimated using methods in Bernard and Clark (1996). In this section we are reporting on statistics from wild smolt tagging in 1991-2002 and adult returns in 1992-2003.

*5.4.2.1 Releases*

As experience and trapping methods have improved, both the number of coho smolt and the marked fraction with CWTs has increased (Figure 5-14). The average number of smolt tagged from 1991-1998 was 11,151 and was more than tripled (37,411) from 1999-2002. The marked percent has doubled from about 1% to 2%, on average, over the two time frames.

*5.4.2.2 Total Return from Release*

Marine survival has averaged 11.3% from 1992-2003, with averages of 12.7% from 1992-1999 and 8.8% from 2000-2003. This compares to the long-term average of about 10% for Southeast Alaska (SEAK) coho stocks since 1980.

For the last 4 complete return years (2000-2003) for which data are compiled, 31% of the return was harvested in landed catch and 68% returned to the escapement (Table 5-9). One-half (16%) of the landed catch was taken in the SEAK troll fishery, 9% in the SEAK drift gillnet fishery, 4% in the sport fishery, 2% in the inriver Canadian gillnet fishery and 1% in the SEAK seine fishery (Table 5-10). No straying of Taku wild coho salmon have been documented to any nearby natural spawning escapements nor hatcheries.

From 1992-1999, harvest rates were higher, with 55% of the return harvested in landed catch and 45% accruing to escapement. Of the landed catch, 25% was taken in the SEAK troll fishery, 19% in the SEAK drift gillnet fishery, 4% in the sport fishery, 5% in the inriver Canadian gillnet fishery and 2% in the SEAK seine fishery (Figure 5-15).

Table 5-9. Summary of population parameters for the Taku River coho salmon run, 1987–2003 (Jones et al. 2006, Appendix F-1).

| Coho salmon above Canyon Island | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Calendar year | Escape-ment | Canadian harvest | Inriver run | Est'd U.S. marine harvest | Estimated total run | Total ER (%) | U.S. marine ER (%) | Smolt in year (t-1) | Marine survival (%) |
| 1987 | 55,457 | 6,519 | 61,976 | | | | | | |
| 1988 | 39,450 | 3,643 | 43,093 | | | | | | |
| 1989 | 56,808 | 4,033 | 60,841 | | | | | | |
| 1990 | 72,196 | 3,685 | 75,881 | | | | | | |
| 1991 | 127,484 | 5,439 | 132,923 | | | | | | |
| 1992 | 84,853 | 5,541 | 90,394 | 96,283 | 186,677 | 54.5 | 51.6 | 743,000 | |
| 1993 | 109,457 | 4,634 | 114,091 | 97,758 | 211,849 | 48.3 | 46.1 | 1,510,000 | 14.0 |
| 1994 | 96,343 | 14,693 | 111,036 | 228,607 | 339,643 | 71.6 | 67.3 | 1,476,000 | 23.0 |
| 1995 | 55,710 | 13,738 | 69,448 | 111,571 | 181,019 | 69.2 | 61.6 | 1,525,000 | 11.9 |
| 1996 | 44,635 | 5,052 | 49,687 | 44,529 | 94,216 | 52.6 | 47.3 | 986,489 | 9.6 |
| 1997 | 32,345 | 2,690 | 35,035 | 15,825 | 50,860 | 36.4 | 31.1 | 759,763 | 6.7 |
| 1998 | 61,382 | 5,090 | 66,472 | 53,368 | 119,840 | 48.8 | 44.5 | 853,662 | 14.0 |
| 1999 | 60,768 | 5,575 | 66,343 | 50,789 | 117,132 | 48.1 | 43.4 | 1,184,195 | 9.9 |
| 2000 | 64,700 | 5,447 | 70,147 | 38,971 | 109,118 | 40.7 | 35.7 | 1,728,240 | 6.3 |
| 2001 | 104,394 | 3,099 | 107,493 | 55,264 | 162,756 | 35.9 | 34.0 | 1,846,629 | 8.8 |
| 2002 | 219,360 | 3,802 | 223,162 | 80,046 | 303,208 | 27.7 | 26.4 | 2,718,816 | 11.2 |
| 2003 | 183,038 | 3,717 | 186,755 | 78,277 | 265,032 | 30.9 | 29.5 | 2,988,349 | 8.9 |
| Standard errors | | | | | | | | | |
| 1992 | 19,033 | | 19,033 | 24,005 | 30,635 | | 8.20 | 247,000 | |
| 1993 | 17,503 | | 17,503 | 19,256 | 26,022 | | 6.20 | 418,051 | 4.2 |
| 1994 | 6,529 | | 6,529 | 36,734 | 37,310 | | 3.80 | 368,411 | 6.3 |
| 1995 | 3,242 | | 3,242 | 12,186 | 12,610 | | 2.80 | 339,822 | 2.8 |
| 1996 | 3,650 | | 3,650 | 6,494 | 7,449 | | 4.10 | 214,152 | 2.2 |
| 1997 | 4,120 | | 4,120 | 2,691 | 4,921 | | 4.40 | 154,051 | 1.5 |
| 1998 | 5,394 | | 5,394 | 7,435 | 9,186 | | 4.00 | 147,260 | 2.6 |
| 1999 | 7,049 | | 7,049 | 6,097 | 9,320 | | 3.90 | 207,576 | 1.9 |
| 2000 | 5,667 | | 5,667 | 3,326 | 6,571 | | 2.59 | 255,147 | 1.0 |
| 2001 | 9,495 | | 9,495 | 4,828 | 10,652 | | 2.75 | 276,385 | 1.4 |
| 2002 | 28,648 | | 28,648 | 6,389 | 29,352 | | 2.92 | 363,071 | 1.8 |
| 2003 | 17,724 | | 17,724 | 10,271 | 20,485 | | 3.32 | 1,008,886 | 3.1 |

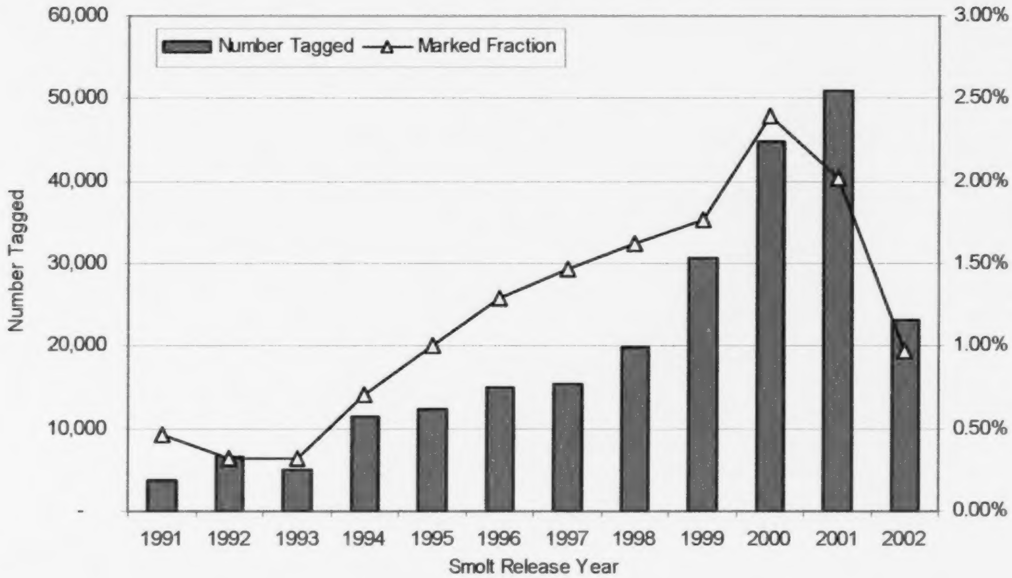


Figure 5-14. Releases of tagged smolt and the estimated marked percent of coho salmon from the Taku River 1991-2002.

Table 5-10. Number of estimated tagged Taku River coho salmon returning to escapement and fisheries for calendar years 2000-2003.

| | 2000 | 2001 | 2002 | 2003 | Average |
|---|---|---|---|---|---|
| Escapement | 372 | 768 | 788 | 322 | 563 |
| Inriver Canadian Gillnet | 28 | 50 | 70 | 32 | 45 |
| Alaska Drift Gillnet | 168 | 79 | 143 | 56 | 112 |
| Alaska Sport | 175 | 274 | 494 | 245 | 297 |
| Alaska Purse Seine | 96 | 74 | 77 | 36 | 71 |
| Alaska Troll | 1,139 | 2,495 | 4,431 | 1,775 | 2,460 |
| Total | 1,978 | 3,740 | 6,003 | 2,467 | 3,547 |

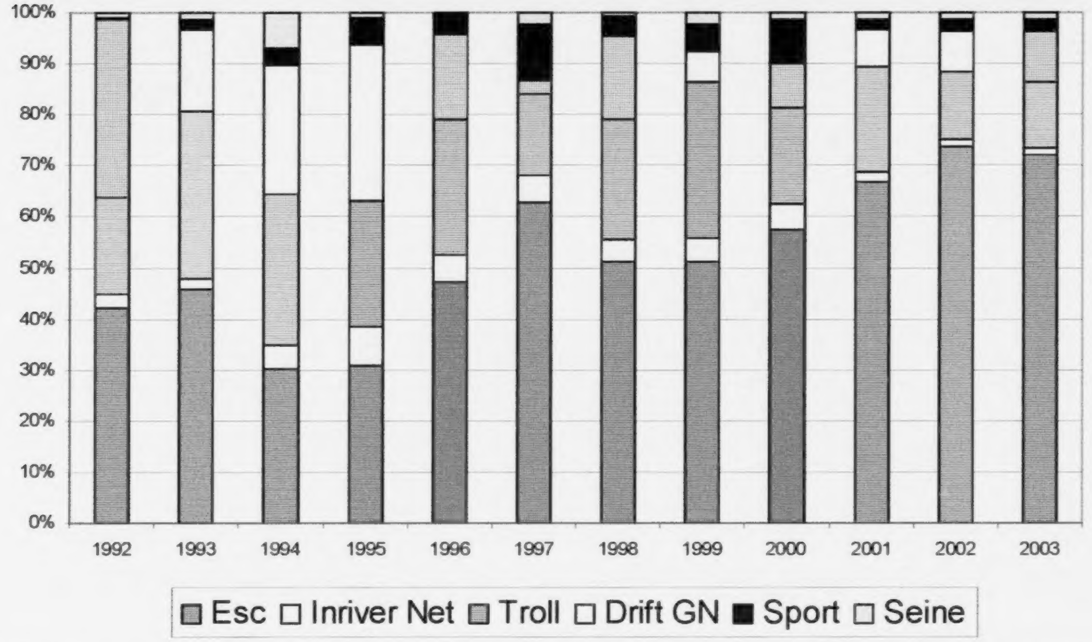


Figure 5-15. Percent of total return by gear sector and escapement for tagged Taku River coho salmon for calendar years 1992-2003.

*5.4.2.3 Sampling in Fisheries and Escapement.*

An examination of the number of tagged fish recovered in fisheries and escapement shows that there has been an increase in the number of tagged fish observed in samples (Figure 5-16). This is a direct result of increased numbers of tagged fish. From 1992-1999 an average of 160 observed randomly sampled CWTs were recovered from marine fisheries and a total of 180 in all fisheries and escapement, compared to 289 recovered in fisheries and 338 total from 2000-2003. Sampling rates in marine fisheries has averaged 28% from 1992-2003, with no discernable change in these rates, for fishery strata in which Taku River coho salmon are recovered. Sampling rates in the escapement have averaged 3.2% from 1992-2003, which is not a high rate, but constitutes an average of 2,500 adults examined during the marking event in the escapement assessment program. This level of sampling has produced population statistics with acceptable levels of precision for management (see following section).

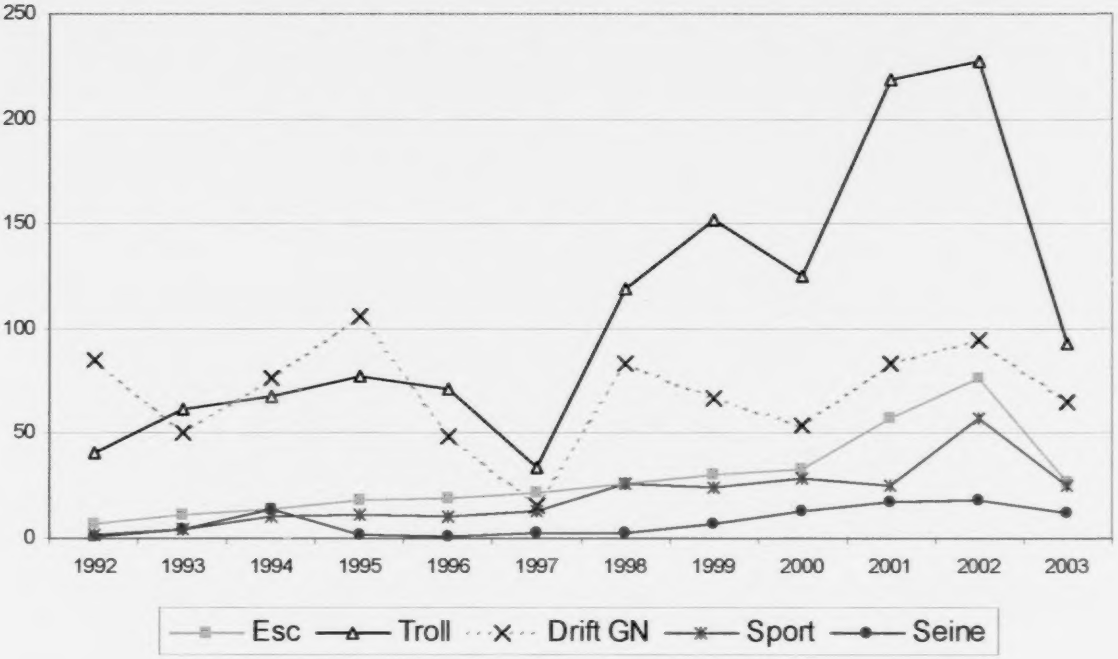


Figure 5-16. Number of observed CWT recoveries of Taku River coho salmon in sport, troll and net fisheries.

### *5.4.2.4 ERs and Population Statistics Precision*

The Taku River annual ERs have decreased from approximately 49% for 1992-1999 to about 31% for 2000-2003 (Table 5-11). The precision of the ERs, as judged by the PSE, has remained about the same over the time series, averaging about 10%. As the ERs have decreased over time, the precision of the marine harvest and total run estimates have improved, which is the primary reason that the precision of the ERs has not changed.

Table 5-11. Estimated annual marine ERs for Taku River coho salmon and percent standard errors (PSE = SE/estimate x 100) for various population statistics.

| Adult Return Year | PSE Estimated Smolt | PSE Estimated Marked Fraction | PSE Estimated Marine Harvest | PSE Estimated Esc | PSE Estimated Inriver Run | PSE Estimated Total Run | PSE Estimated Marine Survival | PSE Estimated Marine ER | Estimated Marine ER |
|---|---|---|---|---|---|---|---|---|---|
| 1992 | 33% | 38% | 25% | 22% | 21% | 16% | | 16% | **52%** |
| 1993 | 28% | 30% | 20% | 16% | 15% | 12% | 30% | 13% | **46%** |
| 1994 | 25% | 27% | 16% | 7% | 6% | 11% | 27% | 6% | **67%** |
| 1995 | 22% | 23% | 11% | 6% | 5% | 7% | 24% | 5% | **62%** |
| 1996 | 22% | 23% | 15% | 8% | 7% | 8% | 23% | 9% | **47%** |
| 1997 | 20% | 21% | 17% | 13% | 12% | 10% | 22% | 14% | **31%** |
| 1998 | 17% | 19% | 14% | 9% | 8% | 8% | 19% | 9% | **45%** |
| 1999 | 18% | 18% | 12% | 12% | 11% | 8% | 19% | 9% | **43%** |
| 2000 | 15% | 17% | 9% | 9% | 8% | 6% | 16% | 7% | **36%** |
| 2001 | 15% | 13% | 9% | 9% | 9% | 7% | 16% | 8% | **34%** |
| 2002 | 13% | 11% | 8% | 13% | 13% | 10% | 16% | 11% | **26%** |
| 2003 | 34% | 19% | 13% | 10% | 9% | 8% | 35% | 11% | **30%** |
| Averages | | | | | | | | | |
| 1992-2003 | 21.8% | 21.7% | 14.0% | 11.1% | 10.3% | 9.2% | 22.4% | 9.8% | **43.2%** |
| 1992-1999 | 23.1% | 25.0% | 16.1% | 11.5% | 10.6% | 10.0% | 23.4% | 10.0% | **49.1%** |
| 2000-2003 | 19.2% | 15.2% | 9.6% | 10.1% | 9.8% | 7.5% | 20.7% | 9.4% | **31.4%** |

### 5.4.3 Black Creek Coho Salmon

Tagging of wild coho salmon smolts began at Black Creek in 1976. The stock represents the freshwater survival, marine survival, and fishery impacts of wild coho salmon in the Georgia Strait, east coast Vancouver Island region. The tagged fraction of the freshwater production is estimated the following year by sampling mark rates in the adult spawning escapement.

#### *5.4.3.1 Releases*

Strategies for smolt tagging targets have varied among years; however, often all captured wild smolts were tagged and adipose fin clipped, except in recent years when adipose fins were not clipped. On average, more than 45,000 wild smolts were tagged annually, ranging from about 8,000 to 150,000 smolts (Figure 5-17). Tagged fish represent an average of 62% of the surviving freshwater production, ranging from 5% to 90%. Freshwater production likely originates from Black Creek and other nearby systems.

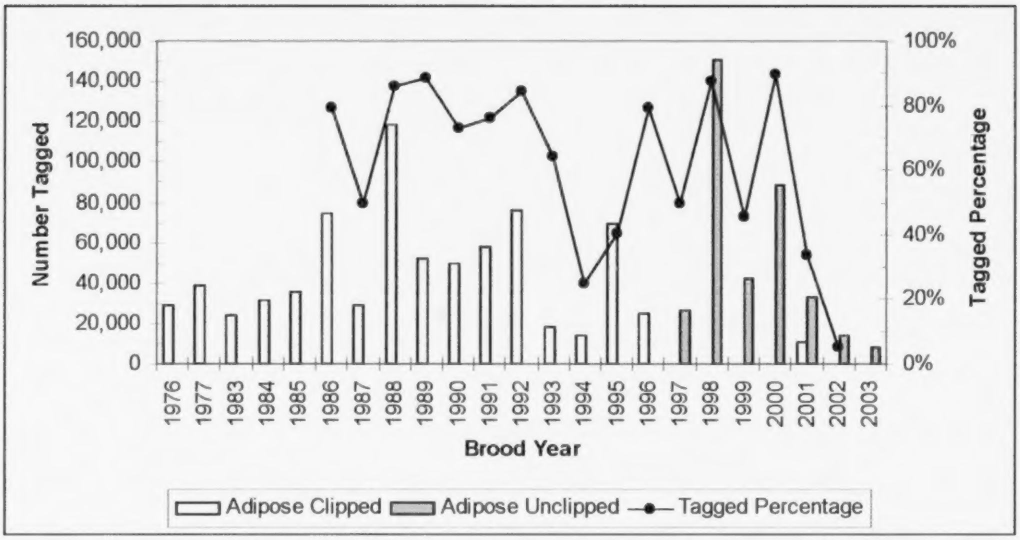


Figure 5-17. Numbers of tagged wild coho salmon smolts at Black Creek for brood years 1976-2003, and the estimated percentage tagged among age-3 adults on the spawning grounds.

*5.4.3.2 Returns from Releases*

The percentage of tagged releases returning to fisheries and escapement has been fairly high with an average survival index (excluding incidental mortalities) of 10%, ranging from 2% to 19% between brood years 1983 and 2002 (Figure 5-18). After brood year 1996, adipose fins were not clipped from tagged fish, except for 2001, and very few recoveries were made from mark selective or visually sampled fisheries. Overall, the percentage of tagged fish returning to fisheries and escapement has been declining steadily since the mid 1980's.

For brood years 1990-1994, average annual estimated CWT recoveries were highest in the WCVI troll, Strait of Georgia sport, and Southern BC net fisheries and about 64% of recoveries were at the spawning grounds (Table 5-12). After brood year 1994, nearly all the CWT recoveries occurred on the spawning grounds largely due to reduced fishing impacts, reduced adipose fin clipping of tagged smolts, and implementation of hatchery-mark selective fishing methods (Figure 5-19).

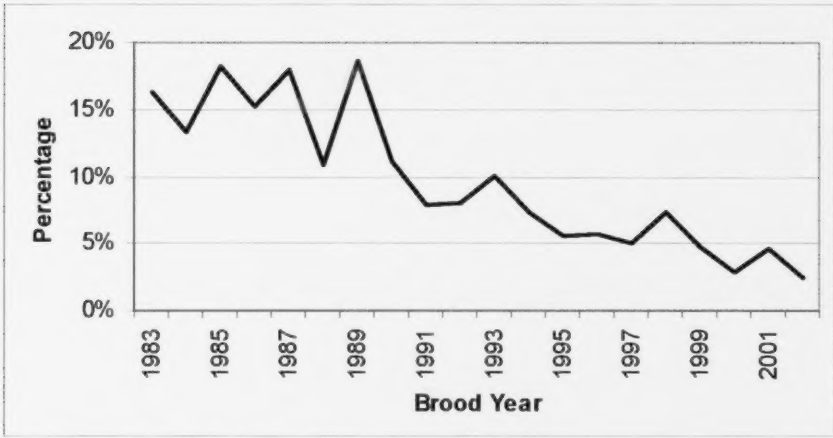


Figure 5-18. Percentage of total CWT releases estimated to return to fisheries and escapement for Black Creek coho salmon for brood years 1983-2002. Note that after brood year 1996, adipose fin clipping of CWT fish was limited.

Table 5-12. Number of estimated tagged Black Creek coho salmon returning to escapement and fisheries averaged over brood years 1990-1994. Note that after brood year 1994, fisheries were shaped to reduce impacts on coho stocks of concern and after 1996, adipose fin clipping of CWT fish was limited.

| | Age 3 Estimated CWTs |
|---|---|
| Escapement | 833 |
| WCVI Troll | 597 |
| Georgia Strait Sport | 479 |
| Southern B.C. Net | 168 |
| NCBC Troll | 126 |
| SEAK Troll | 63 |
| NCBC Sport | 58 |
| WCVI Sport | 48 |
| WA Net | 26 |
| SEAK Net | 24 |
| NCBC Net | 22 |
| Puget Sound Sport | 13 |
| Terminal Sport | 9 |
| Washington Ocean Sport | 5 |
| WCVI Net | 3 |
| Washington Ocean Troll | 2 |
| Oregon Sport | 2 |

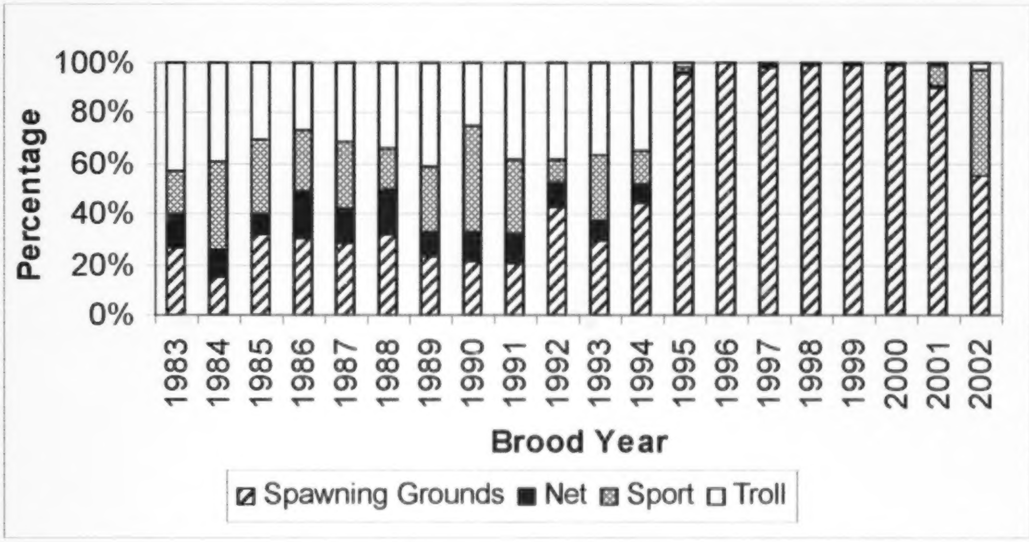


Figure 5-19. Percentage of estimated tag recoveries occurring in net, sport, and troll fisheries and on the spawning grounds for brood years 1983-2002. Note that after brood year 1994, Canadian fisheries were shaped to reduce impacts on coho stocks of concern and after 1996, adipose fin clipping of CWT fish was limited.

*5.4.3.3 Sampling in Fisheries and Escapement*

Observed tags peaked in fisheries and escapement in the late 1980's and declined to low levels by brood year 1993 (Figure 5-20). Fishery recoveries were rare for brood years that were not adipose fin-clipped. At the spawning grounds, CWT sampling occurred until brood year 1998 returned, and since then no CWTs have been sampled (no heads collected for CWT dissection). Beginning with brood year 1996, electronic detection equipment (detector wands) was used to identify fish presumed to contain a CWT. For brood years 1998-2002, on average 57% of the estimated spawning escapement was examined for the presence of a CWT using electronic detection equipment.

Recently (brood years1998-2002), fisheries have reported a much smaller number of recovered tags than for brood years 1976 and 1977, for both pre-terminal and terminal fisheries (Table 5-13). For troll and net fisheries, average sample rates appear similar between these time periods; however, the average sample rates have decreased recently for the sport fisheries. In both time periods, pre-terminal fisheries accounted for more estimated age-3 recoveries than terminal fisheries, which were defined as freshwater sport recoveries and all fishery recoveries occurring between October and December.

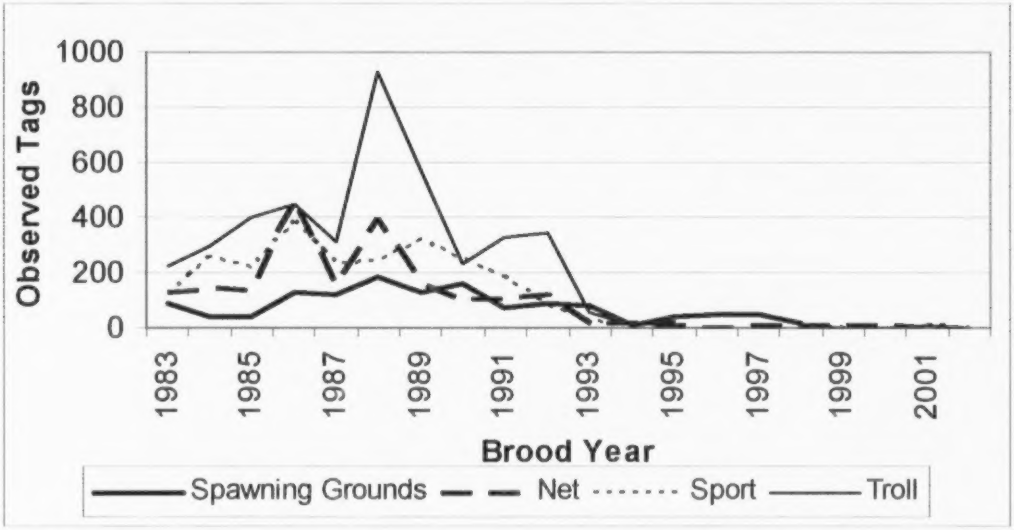


Figure 5-20. Number of observed CWT recoveries for Black Creek coho salmon at spawning grounds and in sport, troll and net fisheries.

Table 5-13. Number of age-3 tagged Black Creek coho salmon recovered in samples, estimated number, percentage (%) in samples (observed/estimated), and PSE for pre-terminal and terminal fisheries summarized for early brood years (1976 and 1977) and available for last five completed brood years (1998-2002).

| | | 1976 and 1977 | | 1998-2002 | |
|---|---|---|---|---|---|
| | | Pre-Terminal | Terminal | Pre-Terminal | Terminal |
| Spawning Grounds[1] | Sum of observed | | | | 1,087[1] |
| | Sum of estimated | | No | | 3,314 |
| | % in samples | | Sampling | | 57% |
| | PSE | | | | 7% |
| Net | Sum of observed | 446 | 17 | 3 | 3 |
| | Sum of estimated | 1,196 | 44 | 7 | 5 |
| | % in samples | 32% | 38% | 44% | 71% |
| | PSE | 5% | 35% | 47% | 31% |
| Sport | Sum of observed | 536 | 15 | 3 | <1 |
| | Sum of estimated | 2,445 | 69 | 48 | 1 |
| | % in samples | 22% | 22% | 11% | 15% |
| | PSE | 4% | 26% | 67% | 102% |
| Troll | Sum of observed | 562 | 3 | 4 | 0 |
| | Sum of estimated | 2,062 | 9 | 16 | 0 |
| | % in samples | 27% | 40% | 31% | NA |
| | PSE | 5% | 46% | 60% | NA |

[1]No heads were collected to decode CWTs. All fish with positive electronic detections were assumed to carry a Black Creek CWT (an observed tag) and be 3-year olds.

*5.4.3.4 ERs and Precision*

ERs generally ranged from 75% to 85% between brood years 1983 and 1993 and then declined rapidly to low levels when fisheries were shaped to reduce impacts on stocks of concern (Figure 5-21). Pre-terminal fisheries experienced the largest reductions, although the terminal fishery ERs have been declining since the mid 1980s (Figure 5-22). The precision of the ERs, as judged by the PSEs, increased after 1992. Further, standard errors were likely under-estimated when electronic detection equipment identified fish presumed to contain a CWT, as detections were not adjusted for false positive or negative errors.

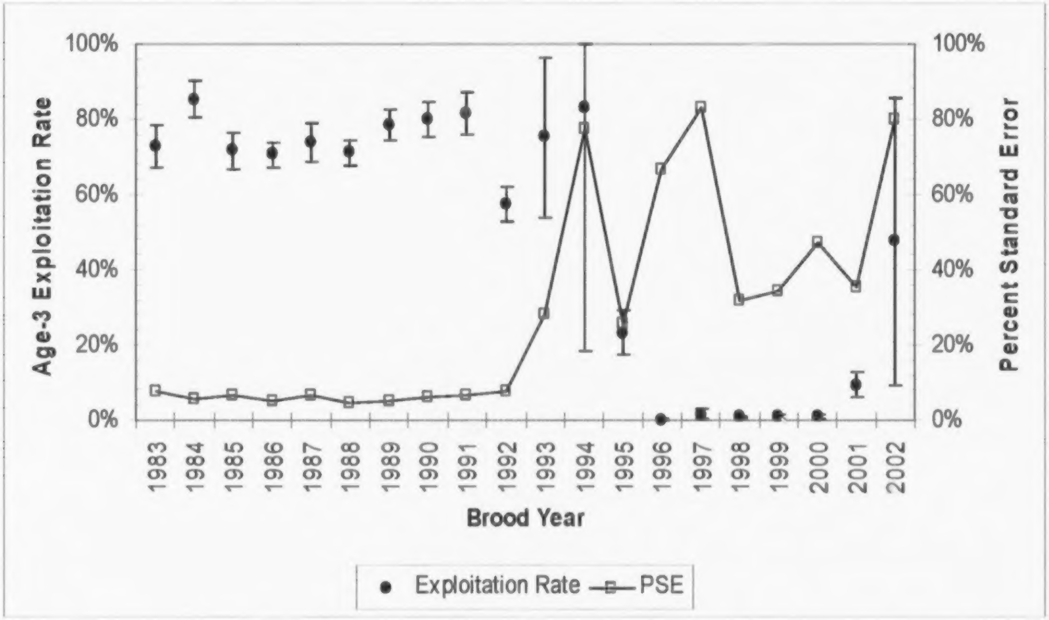


Figure 5-21. Age-3 ERs (excluding incidental mortalities) and percent standard errors (PSE) for Black Creek coho salmon brood years 1983-2002. Error bars represent one standard error.

*5.4.3.5 Conclusion*

- In the recent period, essentially all the fisheries have average PSE's that exceed the 30% benchmark identified in Chapter 5.
- Exploitation rate estimates became less precise, as indicated by increasing PSEs, when non-selective fisheries were closed and when fishing impacts were mainly from mark selective fisheries. However, the absolute precision was excellent given the extremely small ER measured from tag recoveries during most of the period when fisheries were mark selective.

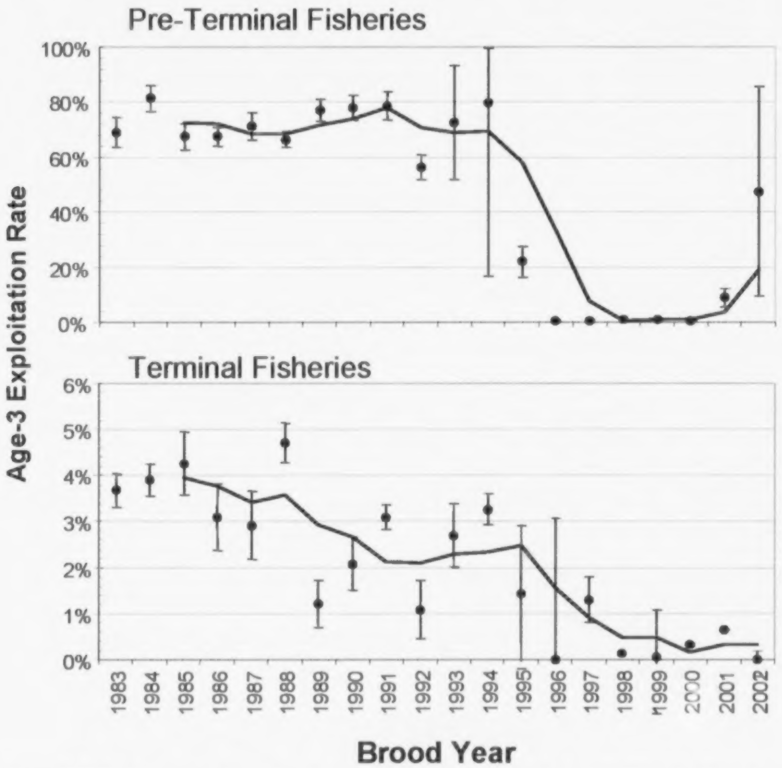


Figure 5-22. Age-3 ERs for pre-terminal and terminal fisheries for Black Creek coho salmon brood years 1983-2002. Error bars represent one standard error and solid lines represent a running three-year average.

### 5.4.4 Queets River Coho Salmon

Queets River fall coho salmon are released from Salmon River Hatchery on a tributary to the Queets on the Washington coast.

#### *5.4.4.1 Releases*

With a few exceptions, approximately 75,000 fingerlings per tag group have been released for this stock since 1983 (Figure 5-23). Since 1995, a DIT has been released from Salmon River Hatchery, with 75,000 marked and 75,000 unmarked tagged fish released.

#### *5.4.4.2 Total Return from Releases*

The percent of the total release estimated to have returned to fisheries and escapement has averaged 2.3% for brood years 1985-2002, ranging from 0.4% to 7.9% (Figure 5-24).

Until 1992 all escapement sampling occurred in the hatchery, since then samples are taken in the hatchery and on the spawning ground (Figure 5-25). For brood years 1983-1993 the troll and net fisheries were taking equal numbers of tagged fish, but since 1993 the net fishery has taken the majority of the tagged fish, while the sport fishery has taken 10-20% of the total tagged return (Figure 5-25).

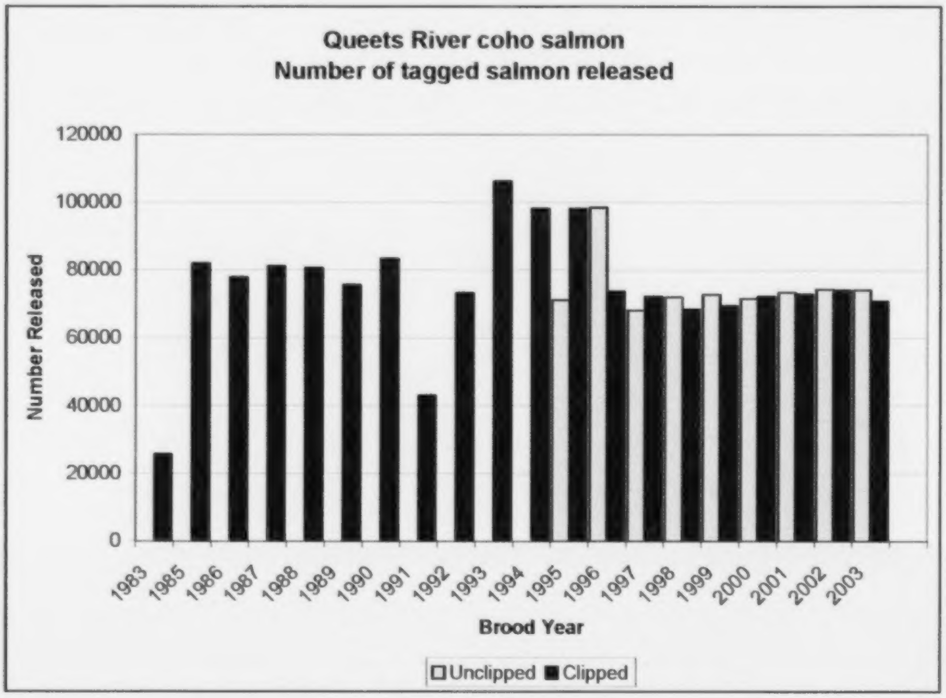


Figure 5-23. Releases of tagged coho salmon for Queets coho salmon 1983-2003.

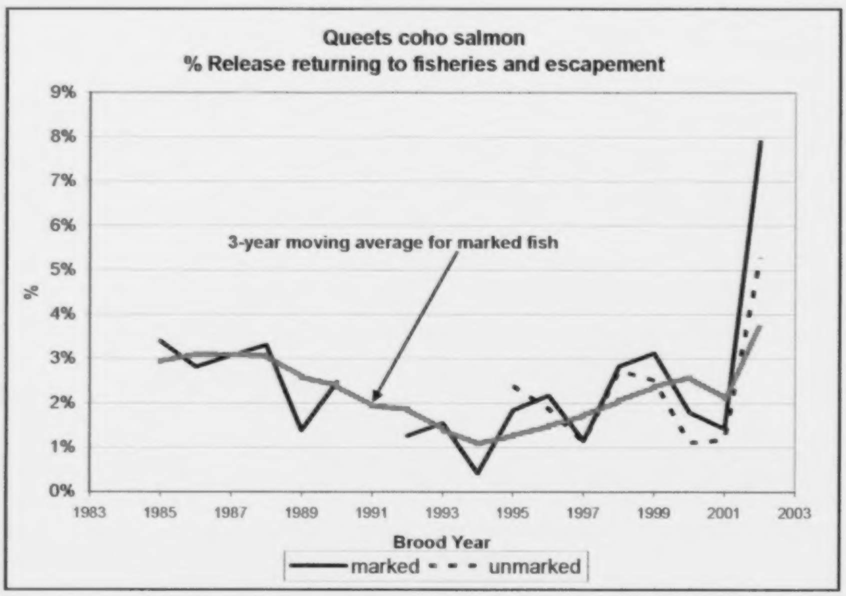


Figure 5-24. Percent of total releases returning to fisheries and escapement for Queets River coho salmon brood years 1983-2002.

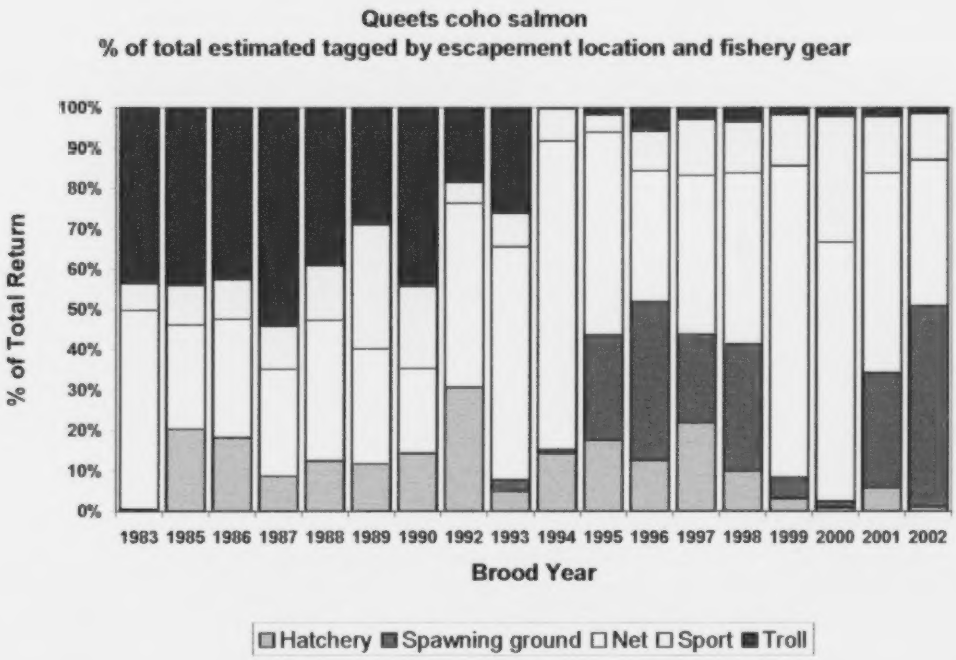


Figure 5-25. Percent of total estimated tags by escapement recovery location or fishery gear type for Queets coho salmon brood years 1983-2002. The spawning grounds were not sampled for CWTs prior to 1993.

### *5.4.4.3 Sampling in Fisheries and Escapement*

An examination of the number of tagged fish recovered in fisheries and escapement shows that there is a general decrease in the total number of tagged fish observed in fishery and escapement samples (Figure 5-26), largely due to a decrease in the size of the troll fishery and to a decrease in recoveries in escapement. Before 1994, troll fisheries were the dominant fisheries (Figure 5-25) while net fisheries take a larger proportion after 1994. Sample rates have remained at levels well above 20% in the fisheries and tag recoveries have not decreased in the sport and net fisheries. However, spawning ground escapement represents a large proportion of the total return after 1994, and the sample rate is substantially lower on the spawning ground and far fewer tags are taken in escapement for the last five brood years as a result (Figure 5-26 and Table 5-14).

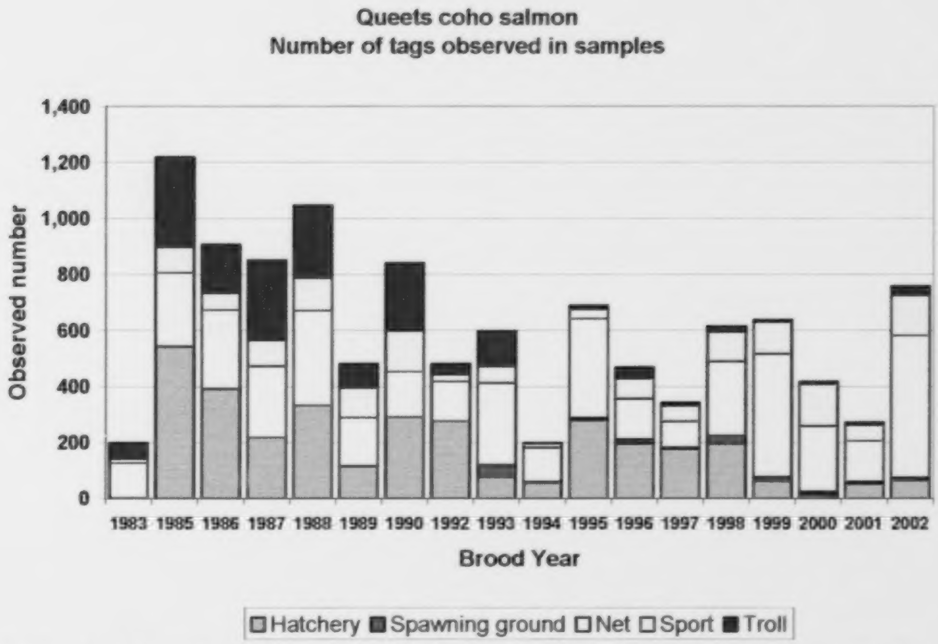


Figure 5-26. Number of observed CWT recoveries for Queets River coho salmon in sport, troll and net fisheries and in escapement. The spawning grounds were not sampled for CWTs prior to 1993.

### *5.4.4.4 Summary*

The Queets River coho salmon total ERs average 74% and 68% for the brood years 1983-1994 and 1995-2002 (Table 5-15). Sport and net fisheries have increased average ER in the latter period, while the troll ER has decreased. This is largely due to the decreased exploitation in the B.C. WCVI troll fishery. A comparison of the PSE of ERs between the two periods shows a decrease in precision for the latter period. This is generally due to the decrease in the number of recoveries from escapement and decrease in ER in the troll fishery.

Table 5-14. Average number of tagged Queets River coho salmon recovered annually in samples, estimated number, % in samples and PSE for pre-terminal and terminal fisheries summarized for brood years from 1983-1994 and 1994-2002.

| | | | 1983-1994 | 1995-2002 |
|---|---|---|---|---|
| Pre-Terminal | Sport | Observed | 71 | 80 |
| | | Estimated | 205 | 232 |
| | | % in Sample | 37% | 39% |
| | | PSE | 19% | 17% |
| | Troll | Observed | 159 | 31 |
| | | Estimated | 665 | 106 |
| | | % in Sample | 51% | 64% |
| | | PSE | 19% | 38% |
| Terminal | Hatchery | Observed | 231 | 133 |
| | | Estimated | 238 | 143 |
| | | % in Sample | 97% | 93% |
| | | PSE | 13% | 12% |
| | Spawning ground | Observed | | 13 |
| | | Estimated | | 662 |
| | | % in Sample | | 11% |
| | | PSE | | 37% |
| | Net | Observed | 208 | 252 |
| | | Estimated | 544 | 863 |
| | | % in Sample | 40% | 31% |
| | | PSE | 8% | 7% |

Table 5-15. Estimated annual ERs with PSE for Queets River coho salmon averaged over brood years1983-94 and 1995-2002.

| Fishery | | Statistic | 1983-1994 | 1995-2002 |
|---|---|---|---|---|
| Pre-Terminal | Sport | ER | 10% | 14% |
| | | PSE | 19% | 19% |
| | Troll | ER | 29% | 3% |
| | | PSE | 20% | 36% |
| Terminal | Net | ER | 34% | 49% |
| | | PSE | 9% | 13% |
| Total | | ER | 74% | 68% |
| | | PSE | 8% | 12% |

## *Recommendations and Summary*

The PSC relies on CWT-based estimates, including ERs, to conserve and manage stocks of Chinook and coho salmon. The uncertainty (precision and accuracy) of CWT-based statistics depends on the number of observed CWT recoveries; generally, as the number of observed recoveries increases, uncertainty decreases. Statistical consideration of uncertainty is addressed in detail in Sections 5.1 to 5.3.

The four case studies in Section 5.4 above provide examples of how interactions among tagging levels, survival rates, fishery distributions, and estimates of total catch/escapement affect uncertainty surrounding estimates of ERs for individual stocks. The impacts of these factors vary among stocks. For the Green River Chinook stock (Section 5.4.1), the uncertainty of brood year ERs in pre-terminal fisheries has increased and in terminal fisheries it has decreased, while overall ERs have dropped from 48% to 24% and survival has dropped by 60%. For Taku River wild coho (Section 5.4.2), the relative precision of ERs has remained stable (PSE=10%), even though total ERs have dropped from 55% to 32% while distribution amongst fisheries has remained similar. Maintenance of this precision level can be attributed to increased tagging levels coupled with increased precision in estimates of harvest and total run. For Black River wild coho (Section 5.4.3), ERs and the number of CWTs recovered have both decreased since 1995 due to large reductions in fisheries where this stock is caught and a shift to unclipped releases, resulting in increases in the uncertainty in fishery impacts and statistics. For Queets River coho (Section 5.4.4), ER and their relative precision have remained relatively stable from 1983-2002, but have been commensurate with a shift away from pre-terminal harvests to terminal harvests and escapement.

All the case studies illustrate that changes in survival, ER, harvest allocation, and sampling programs have affected the uncertainty surrounding stock-specific CWT statistics over time. Major factors that can increase or decrease the number of observed CWTs in a given strata, and hence affect uncertainty, are summarized below.

| Factors that increase uncertainty | Factors that decrease uncertainty |
|---|---|
| • Lower survival rates<br>• Smaller CWT release sizes<br>• Lower sampling rates<br>• Unsampled strata (fisheries or escapements)<br>• Lower ER or finer resolution requirements for fishery strata<br>• Sampling methods that are inconsistent or result in bias<br>• Lower reliability of the magnitude of total catches or escapements being sampled | • Higher survival rates<br>• Larger CWT release sizes<br>• Higher sampling rates<br>• Complete sampling of fisheries and escapements<br>• Higher ER or aggregated sampling strata<br>• Consistent, unbiased sampling programs<br>• Increased confidence in reliability of the magnitude of total catches or escapements being sampled |

Examination of Figure 4-2 and Figure 4-3, combined with other general and specific considerations listed above, provides a cursory framework of evaluation for decision makers involved with the CWT programs coastwide. Substantial changes in fisheries, survival, and ERs

have occurred since the mid-1980s which have tended to increase uncertainty surrounding CWT-based statistics.

The reliability of CWT statistics can be improved by undertaking general types of remedial actions for individual stocks or in fisheries harvesting complex stock mixtures. For example, if the overall ER in a particular fishery is so low that the reliability of CWT statistics is unacceptable, increase the tagged release to reduce uncertainty for an individual stock, or increase the sample rate to reduce uncertainty for all affected stocks. If less uncertainty is required to satisfy tolerance requirements for a particular stock, increase the size of CWT release groups, or improve sampling and estimation programs for terminal fishery catches and escapements.

The case studies presented in this chapter demonstrate that remedial actions to reduce uncertainty in CWT statistics are likely to vary by stocks and fisheries. The Workgroup recommends that each agency evaluate its CWT programs in order to determine where the reliability of CWT statistics does not satisfy management needs and identify the strategies that will most efficiently and effectively improve the performance of their CWT programs. Stock-specific and multi-stock issues and solutions should be examined in a comprehensive framework to evaluate trade-offs between investments in tagging levels, fishery/escapement sampling, and estimation. Single-stock tools and multi-stock tools in a decision-theoretic setting which can provide information regarding trade-offs between the costs and impacts of alternative measures are discussed in Chapter 6. The workgroup recommends that a high priority be placed on further development of such tools.

# 6 Decision Theoretic Model

The principal utility of a decision-theoretic model is derived from the imposition of a disciplined structure for identifying and evaluating alternatives. Although it would be developed to address specific issues relating to tagging levels and sampling rates for CWT studies, such a model will need to go beyond matters of experimental design in a statistical sense. Because its purpose is to inform decision making, the model will need to include social values relating to the nebulous socially-defined terms of "costs and benefits". The model would integrate statistical tools and information regarding alternative marking and tagging strategies in the form of an *expert system* that would be designed to provide advice to entities conducting CWT studies or fishery/escapement sampling programs. The presentation of information provided for alternatives should center on describing the consequences and outcomes of decisions in metrics that are relevant and important to the decision-makers responsible for determining budget constraints and operating tagging/sampling programs.

The model could be designed and constructed in a variety of ways to integrate statistical and social considerations involved in the design of CWT studies, but the most straight-forward approach would be to focus on the consequences of error and statistical uncertainty around estimates of ERs. This would provide direct visibility of the trade-offs between investments made in tagging and/or sampling programs and the uncertainty surrounding the estimate of a fishery ER. The model would then translate that uncertainty into metrics that are relevant to decision-makers.

For example, in Figure 6-1, the two curves represent expected distributions of estimates of the ER resulting from different CWT programs. The figure on the left side shows the distributions for an estimate of ER (60%). Although both estimates of ER are the same, the shapes of the curves reflect different levels of uncertainty. The narrower distribution indicates a lower level of uncertainty than the second, wider distribution, indicating that there is less of a chance of estimating an ER that deviates substantially from the mean value.

The significance of the difference between the two distributions depends upon the consequences of uncertainty. For example, if a determination that the ER is above a fixed constraint results in penalty, then the degree of uncertainty becomes relevant in two ways: (1) avoidance of a penalty due to uncertainty of the estimate of ER; and (2) the ability to maximize the harvest for a given level of risk. As the uncertainty in the estimate of ER becomes smaller, there is smaller chance that random error would trigger a penalty when the true ER is within the allowable constraint. Also the smaller the uncertainty, the closer the manager can set the target ER to the allowable constraint. For instance, the degree of uncertainty might be determined by the tagging level and/or sampling rate; the manager's decision is: "are the benefits of reducing uncertainty worth the cost of increasing the tagging level or sampling rate?"

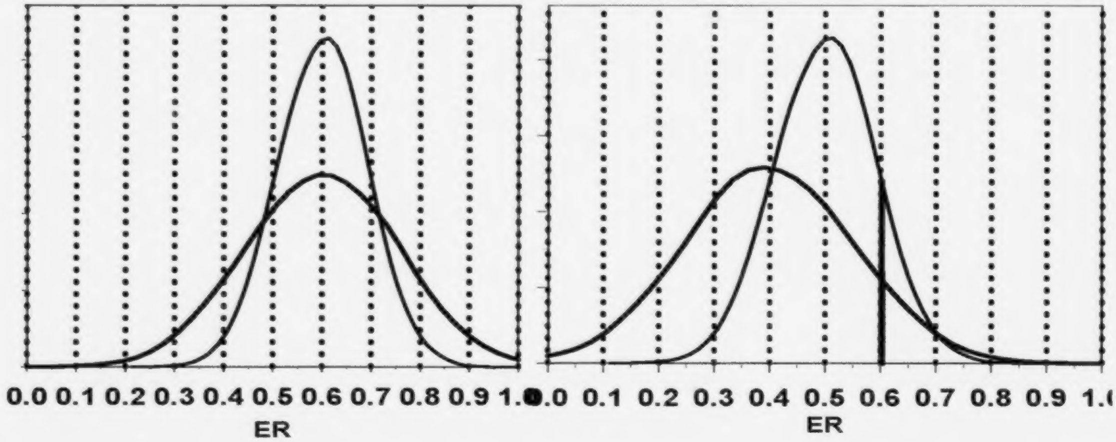


Figure 6-1. Illustration of effects of uncertainty on management decisions. The two curves represent distributions of estimates of the ER resulting from different CWT programs (see text for further explanation).

The example illustrated in the figure on the right side of Figure 6-1 shows the impact of setting an ER management objective. In this example the objective is set at 60% (0.6 in the figure) with the management criteria that the chance of exceeding this constraint should be no larger than 10%. Consequently, the target ER must be lower than the constraint so that the area under the curve to the right of the constraining ER of 60% is no larger than 10%. For the two curves illustrated in the right graph of Figure 6-1 the one with the smaller uncertainty meets this criteria at an ER target of 50%, but the one with the larger uncertainty (wider distribution) must be moved to a target ER of 40% to ensure that there is less than a 10% chance of exceeding the ER constraint of 60%.

The preceding discussion should remind those versed in statistics of Type I and II errors commonly considered in experimental design. Basically, Type I error is the probability that the null hypothesis will be rejected when the hypothesis is in fact true. A Type II error is the analog, the probability that the statistic of interest will lead to the acceptance of the null hypothesis when the hypothesis is in fact false.

How does decision theory utilize the concepts of Type I and II errors and alternative hypotheses? Basically, in decision-theory, probabilities are assigned to reflect the likelihood that a particular hypothesis (or state of nature) is true, and evaluates outcomes in terms of the consequences of alternative decisions. In essence, decision theory assigns pay-offs to correct outcomes and penalties for incorrect ones under uncertainty as to the true level management criteria. These pay-offs and penalties can be uni-dimensional (e.g., money), or multi-dimensional (e.g., dollar outlays and allowable ERs). When pay-offs and penalties are expressed in common terms, optimization strategies can be employed to maximize the expected pay-off or minimize the potential penalties resulting from making erroneous conclusions. The purpose of the model is to inform decision-makers of the consequences using these two type types of error.

In some situations, the options for reducing uncertainty are limited. For example, once CWTs are released, it is obviously not possible to increase the tagging level. Therefore, the only option

to reduce uncertainty is to increase sampling rates to some degree to improve the precision of the estimated ER or to compensate for reduced survivals. If the desire is to reduce the uncertainty surrounding the ER of a particular stock in a given fishery without changing the sampling rate, then the only option would be to increase the tagging level. In both these circumstances the model would provide a means of estimating how much uncertainty could be reduced at what cost (Figure 6-2).

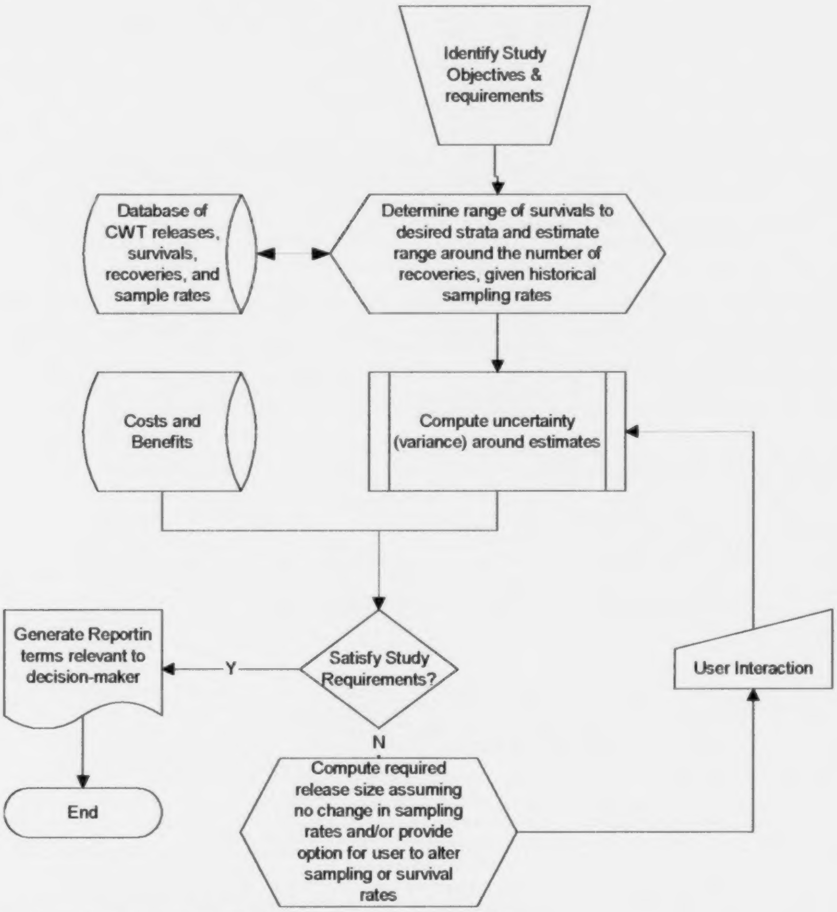


Figure 6-2. General schematic of a decision-theoretic model.

It is also important for the model to recognize that individual experiments are not conducted in isolation. The model will need to integrate and coordinate tagging and recovery strategies across agencies and among fisheries. Tagging agencies rarely have control of all the fishery sampling programs where many of the recoveries occur. It is not a simple matter for tagging agencies to dictate fishery sampling rates because those agencies doing the sampling are operating within their own budget constraints, priorities, and management needs. Within an agency, the effects of uncertainty in one fishery can affect the management of other fisheries. For example, if the management objective is to constrain the total fishery ER to a specified level, the degree of uncertainty in estimates of impacts on one fishery could affect the level of uncertainty allowed in the management of other fisheries. The model will need to take such interactions into account.

At this point the workgroup has not constructed a full model such as that outlined in Figure 6-2. However a proposal for such a model has been constructed by Dr. Gary Morishima and is included in Appendix B.

## *6.1 A Tool to Evaluate Tagging and Sample Rates - Sampling Guidelines Model.*

The simpler planning tool described in this section was developed to provide advice to agencies conducting CWT studies and to fishery and escapement sampling programs, as well as to provide feedback to the PSC. The approach focused on the consequences to error around estimates of ERs to provide direct visibility of the trade-offs between investments made in tagging and/or sampling programs. The coast-wide CWT system is composed of tags released and tags recovered in both fisheries and escapements with the purpose of measuring fishery ERs. Tag recoveries also depend on the numbers of fish sampled and the number of fish in the harvest or escapement of interest. Relative uncertainty in the assessment of a fishery's ER decreases as more tags are recovered in that fishery. Because multiple processes affect the likely number of tags recovered, e.g., tagging levels, survival, maturity, fishery harvest magnitude, and fishery sampling rates, they are the key inputs to determining the level of uncertainty in an ER.

According to our statistical analyses, maintaining a PSE of 30% or less in the ER estimate in one fishery requires that tagging and sampling programs are large enough to recover 10 observed tags from each fishery stratum for the stock or stock-age cohort of interest. The standard of 10 recovered tags has been used to develop guidelines on tagging and sampling rates given long-term average expected survival and fishery ERs. However, those standards are based on calculations that would deliver on average over the long term, 10 tags, meaning in half of the years one would expect less than 10 tags and in the other half more. An alternative is to include an additional factor that would, say, assure at least 10 tags 80% of the time rather than only 50% of the time. Including this factor increases the necessary tagging and or sampling rates.

### 6.1.1 Practical Application of the Tool

The algorithms developed for this tool are shown in Appendix C. At its simplest, the tool can inform decisions on tagging and sampling levels where only one or two tag groups or sampling strata are involved. General trends can be evaluated for either tagging or sample levels given various levels of ER or survival (Figure 6-3 and Figure 6-4). To use this model, the first order of business is to identify the objectives for the CWT study, i.e., the specific statistical questions to be addressed. Some questions central to the design of tagging and sampling programs are clear. What statistic is appropriate for the question to be addressed? What level of accuracy/precision is needed? These questions cannot be dealt with in the abstract; the answers will influence experimental design, data collection, and methods of analysis. For example, examination of Figure 6-3 and Figure 6-4 indicate that given an ER of 5%, tagging 200,000 fish and sampling at 20% is adequate to provide for 10 observed recoveries if survival is 1% or higher. At lower survival levels, tagging and/or sampling levels would need to be higher to achieve 10 observed tags in a fishery with an ER of 5%.

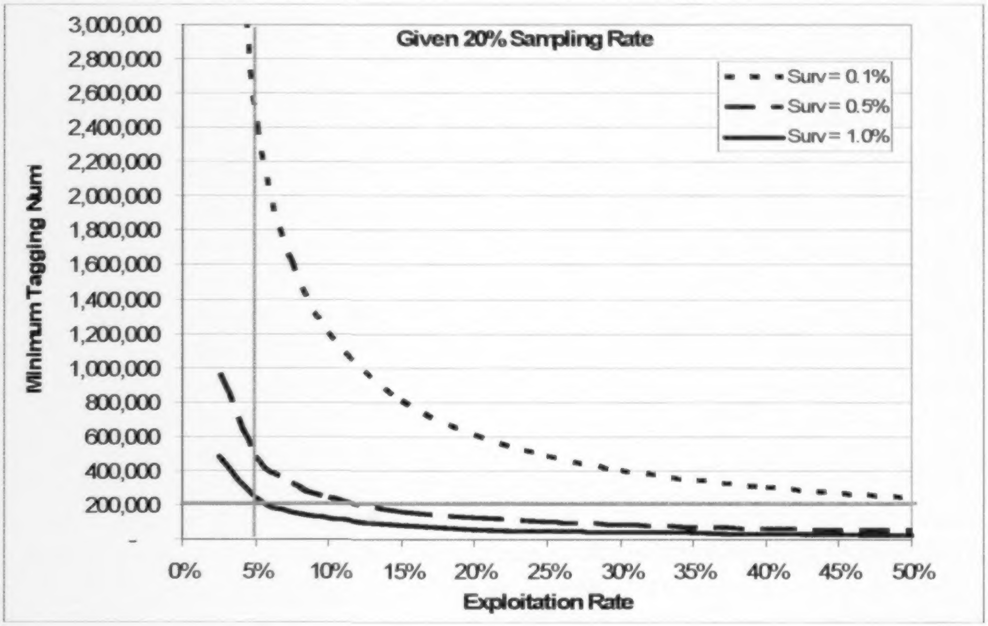


Figure 6-3. Tagging levels required for a single stock versus ER (% of age 2 cohort taken) in a fishery stratum, at three different levels of survival (Surv), necessary to meet a minimum recovery of 10 tags at least 80% of the time given a fishery sampling rate of 20%.

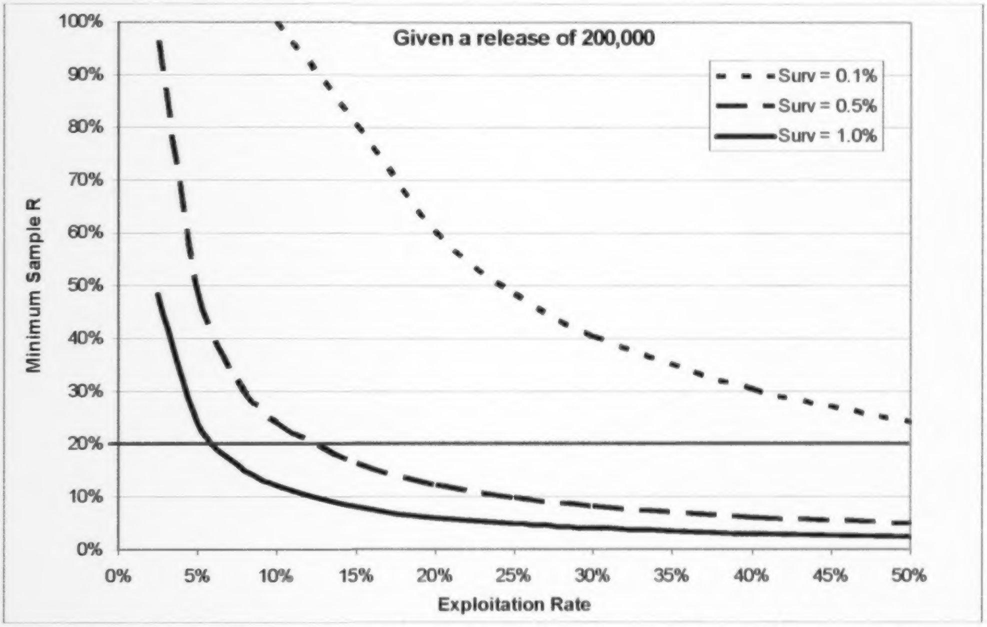


Figure 6-4. Sampling rates required for a fishery versus ER (% of age 2 cohort taken), at three levels of marine survival, necessary to meet a minimum recovery of 10 tags at least 80% of the time, given a release of 200,000 tags for a stock.

The planning tool would be initiated by an inquiry. For instance, say the sponsor wanted to estimate the ER of Stock X at age A in fishery F with confidence level Z. The database would be consulted to evaluate historical patterns of the survival and distribution of recoveries for Stock X, along with information on sampling rates and trends in fishery harvest rates. The user would then perform an analysis, and provide alternatives for consideration (e.g., release R marked fish, or increase sampling rates to S level) in an attempt to help the sponsor minimize cost. The answer for each question will depend on the objectives and the characteristics of the stocks involved. For species or stocks with multiple ages, a tagging target for an older age group will correspond with a survival that has been adjusted for fishing-related mortalities at younger ages in the cohort, fish that matured and left the ocean for the spawning grounds, and natural mortality (see example in Section 6.3).

## *6.2 Chinook Indicator Stocks*

Data from 1971-1999 (brood years) for Chinook indicator tag groups were used to demonstrate historical performance of the tagging and sampling programs relevant to those stocks. Figure 6-3 and Figure 6-4 show that adequate tagging and sampling levels depend highly on survival rates. The average and frequency of historical survival estimates are given in Figure 6-5 and Figure 6-6 for Chinook indicator stocks. Most of these stocks have averages survivals between 0.5 and 1% (Figure 6-5), ranging from 0.2 to 6.0% for brood years with tag data available (Figure 6-6).

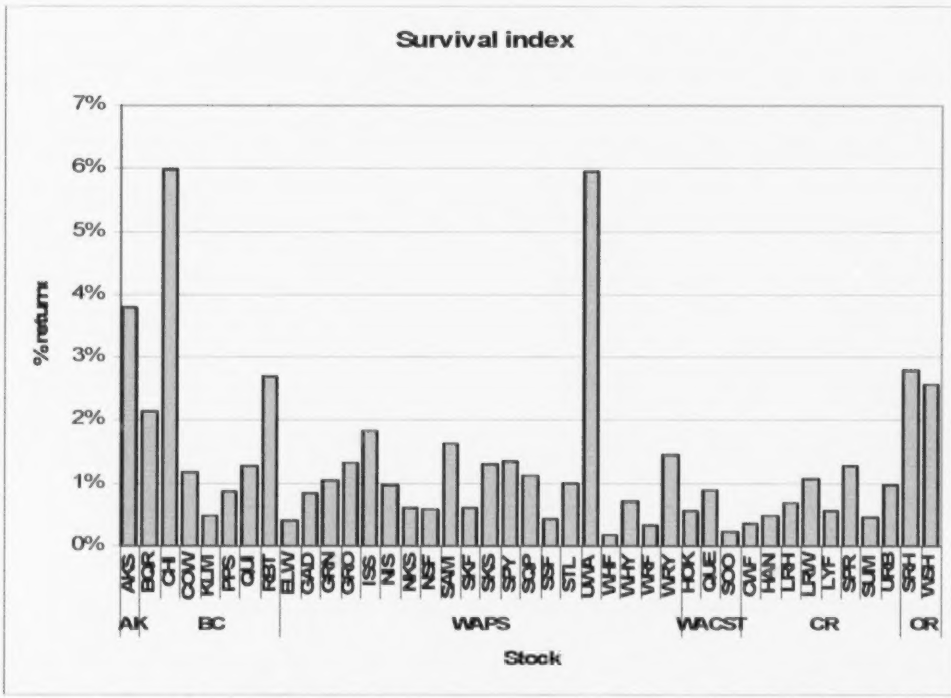


Figure 6-5. Estimated survival (catch+escapement over release) for Chinook salmon indicator stocks averaged over brood years 1971-1999 by stock in each region.

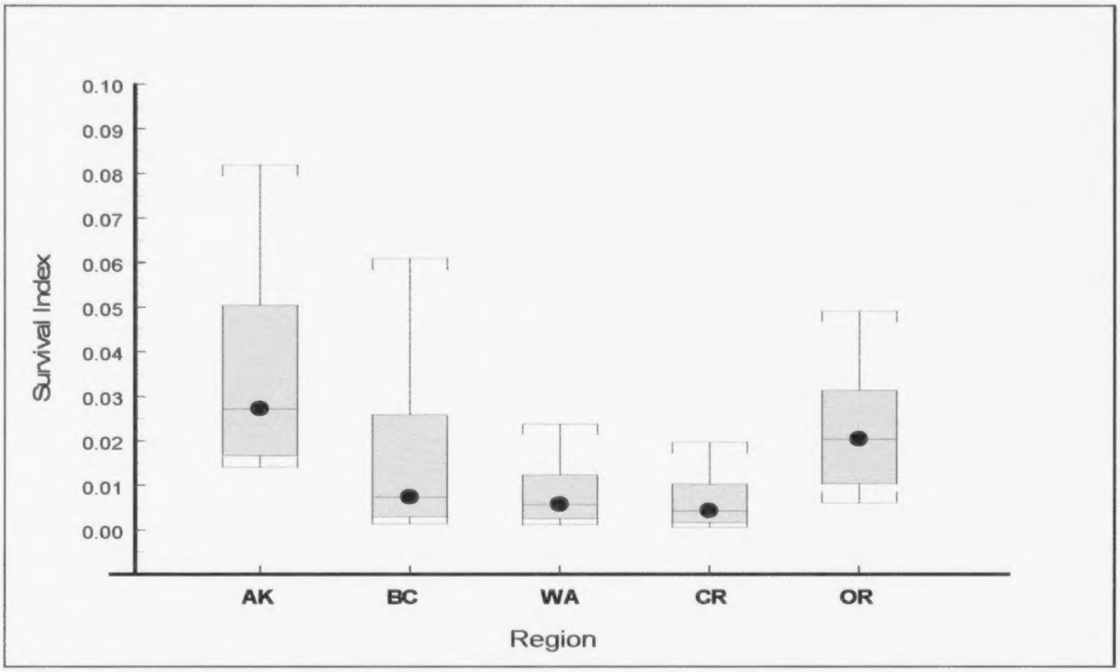


Figure 6-6. Frequency distribution of survival estimates for Chinook indicator tag groups by region of release for brood years 1971-1999. The median and $25^{th}$ to $75^{th}$ quartiles lie within the box with the $10^{th}$ and $90^{th}$ percentiles indicated by the whiskers.

The number of tagged fish released on average for stocks within each of the regions is shown in Figure 6-7 for brood years 1990-2003 and the range of sample rates by fishery area in Figure 6-8. The median release size is at or above 200,000 for all regions. Sample rates shown are for fisheries with direct sampling programs and the median sample rates are over 20% for all regions except the Columbia River (Figure 6-8).

A comparison of the ratio of historical release sizes to the number required to recover at least 10 tags is shown in Figure 6-9. For this comparison tagging levels that would have been required to achieve success at least 80% of the time were calculated given the observed survival, assuming a sampling rate of 20% and an ER of 5%. Actual tagging levels were divided by the required levels. Values greater than 1.0 indicate the tagging level was sufficient to meet the 80% criteria for an ER of 5%.

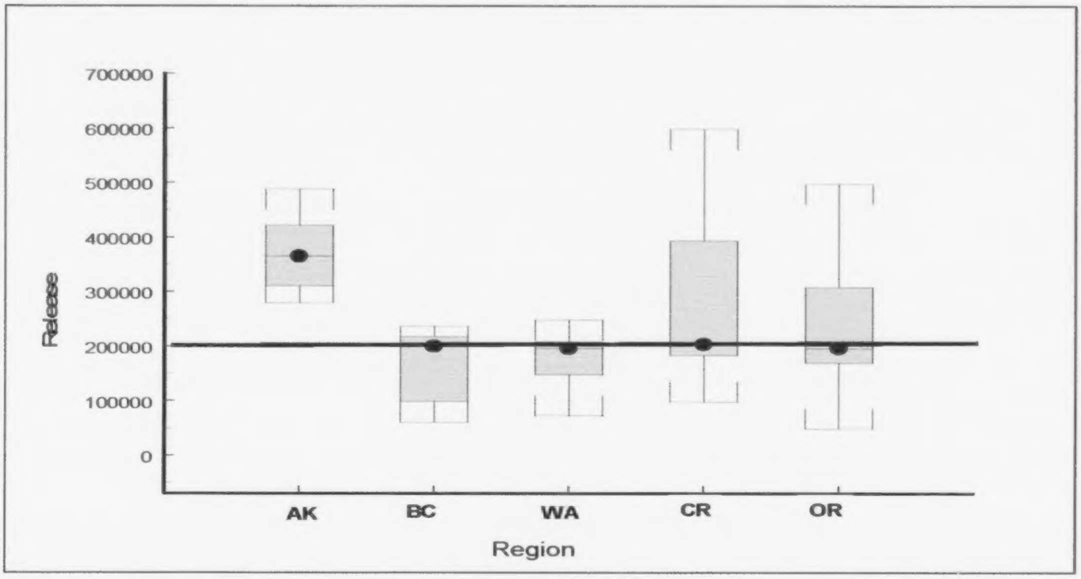


Figure 6-7. Frequency distribution of release size for Chinook indicator tag groups by region of release for brood years 1990-2003. The median and 25th to 75th quartiles lie within the box with the 10th and 90th percentiles indicated by the whiskers. The bold horizontal line indicates the current target of 200,000 CWT release group size.

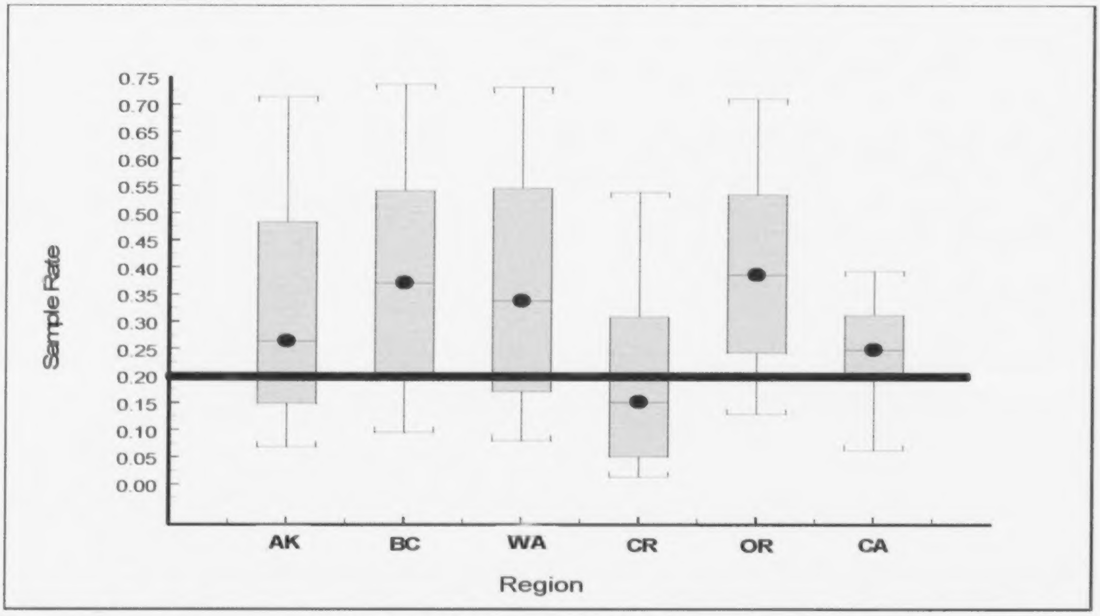


Figure 6-8. Frequency distribution of sample rates for Chinook indicator tag groups by fishery region for catch years 1995-2005. The median and 25th to 75th quartile lie within the box with the 10th and 90th percentile indicated by the whiskers. The horizontal bold line indicates the current target sample rate of 20%.

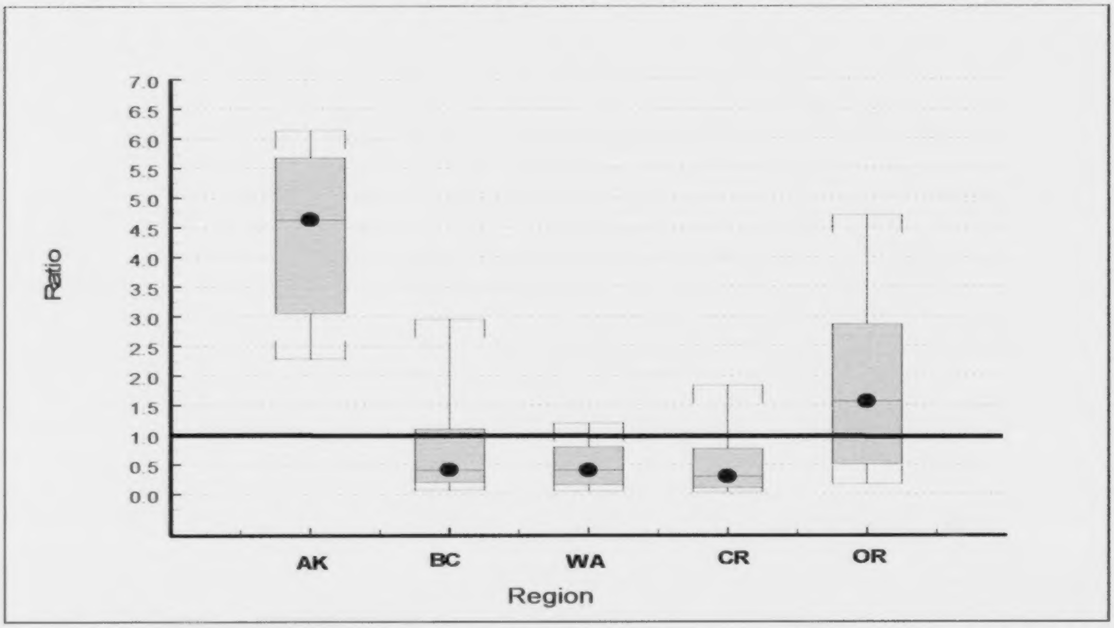


Figure 6-9. Frequency distribution of ratio of observed to required tag releases to achieve goal of 10 observed tagged fish in a fishery with ER of 5% assuming sample rates of 20%. Values greater than 1.0 indicate the tagging level was sufficient to meet the 80% criteria. The median and 25th to 75th quartiles lie within the box with the 10th and 90th percentiles indicated by the whiskers.

This evaluation (Figure 6-9) shows that inadequate numbers of tags have been released historically for stocks within all regions except Alaska and Oregon to achieve the sampling goal of 10 observed tags given sample rates of 20%. In order to achieve the goal, either sample rates must be increased or tagging levels must be increased. The tool introduced in section 6.1 can be used to evaluate what levels of sampling and tagging would be the best use of resources for any indicator stock or fishery. An example is provided in the following section.

## *6.3 Application to the Robertson Creek Chinook Salmon Indicator Stock*

For some Chinook indicator stocks with multiple ages contributing to fisheries, it will be desirable to establish a tagging target using survival to an older age (that is not age 2) for several reasons. For example, the agency releasing the tagged fish may not be responsible for fishery sampling rates and therefore increasing tagging numbers may be the most effective option to improve CWT data quality from fisheries. Furthermore, with Chinook salmon most fishery recoveries occur at one or two ages and a tagging target based on the older age will achieve the target for the younger age. This occurs because a larger tagged cohort is needed for the older age in order to account for natural mortality, fishery exploitation, and maturity factors which reduce the numbers of fish reaching the older age.

The methods to estimate the minimum tagging numbers for a Chinook stock maturing at different ages are demonstrated using the Robertson Creek stock, which matures at ages 2 to 5

with most CWT fishery recoveries being ages 3 and 4. Since brood year 1973, age 2 survival rates have ranged from 0.01% to 21.6% (Figure 6-10), and over the last 20 completed brood years, it equaled or exceeded 0.4% in 16 years (80%) and 2.2% in 14 years (70%). Survivals to age 2 of 0.4% and 2.2% correspond to respective minimum tagging targets of 627,000 and 117,000 fish for the conditions demonstrated in Figure 6-10; an 80% chance of recovering 10 observed tags in a fishery with an ER of 2.5% and a sampling rate of 20%.

To estimate the minimum tagging number for these conditions at age 3, the age 2 survival rate must be adjusted to an age 3 survival rate to account for natural mortality (MORT), ER, and maturation rates (MAT) between ages 2 and 3. The age 2 survival rate is multiplied by the proportion of age 2 fish surviving fishing ($1\text{-}ER_{age\ 2}$), the proportion of fish remaining at sea after maturation ($1\text{-}MAT_{age\ 2}$) and the proportion of fish surviving the natural mortality between age 2 and -3 ($MORT_{age\ 2}$). For a tagging target at age 4, this age 3 survival rate would be further adjusted to account for natural mortality, fishery exploitation, and maturation between ages 3 and 4.

For planning purposes, one can apply average ER for recent brood years, average maturation rates, and the CTC natural mortality rates to estimate the survivals for older fish. To estimate a tagging target for age 3 fish at Robertson Creek, the average age 2 ER (2.3%) for brood years 1995-1999, average age 2 maturation rates for brood years 1980-1999 (excluding 1992: 2.4%), and natural mortality rate between age 2 and -3 (40%) were applied to the expected age 2 cohort survival. To estimate a tagging target for age 4 fish, the average age 3 ER (5.8%) for brood years 1995-1999, average age 3 maturation rates for brood years 1980-1999 (excluding 1992: 15.1%), and natural mortality rate between age 3 and age 4 (30%) were applied to the expected age 3 survival calculated above. After calculating the age specific survival rates, the minimum tagging numbers can be estimated using the tool or Figure 6-3. The minimum tagging numbers needed to achieve a 70% or 80% chance of recovering 10 observed tags in a fishery with an ER of 2.5% and a sampling rate of 20% increase with the age used for planning (Table 6-1).

At Robertson Creek, the tagging target has been 200,000 fish for many years and it was developed when average survival rates and ERs were much higher than they have been recently. From the information provided by the tool, the 200,000 target appears close to achieving the planning conditions for age 3 fish in 7 out of every 10 years over the last 20. Since age 4 fish contribute much of the tag data collected from fisheries and escapements, a tagging target based on age 4 fish would be valuable in terms of improving the CWT data quality for a significant stock used for coastwide abundance forecasting and fishery planning. A tagging target for age 4 fish would require an approximate doubling of the tagging target depending upon how often one aims to achieve the planning conditions. Overall, this tool represents a substantial resource for planning indicator stock programs and improving CWT data quality.

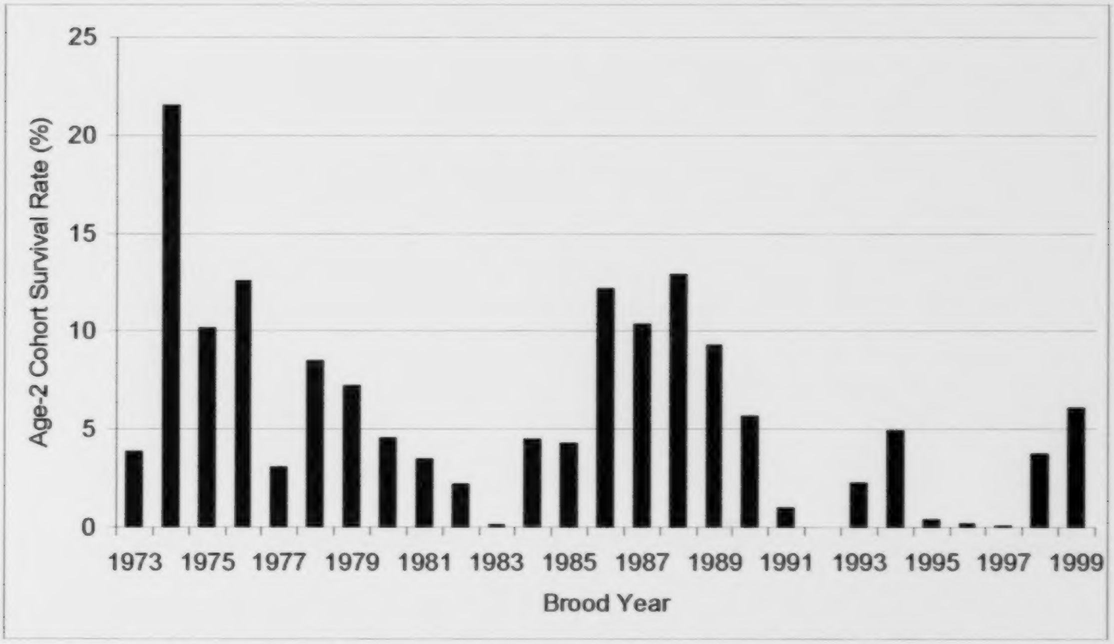


Figure 6-10. Age 2 cohort survival rates for the Robertson Creek Chinook indicator stock for brood years 1973 to 1999.

Table 6-1. Survival rates and corresponding minimum tagging numbers to achieve the conditions depicted in Figure 6-5, while accounting for age-specific fishery exploitation, maturation, and natural mortality for the Robertson Creek Chinook example.

| | **Survival[1]** | | **Minimum Tagging Numbers** | |
|---|---|---|---|---|
| **Age** | **8 of 10 years** | **7 of 10 years** | **8 of 10 years** | **7 of 10 years** |
| 2 | 0.42% | 2.21% | 627,000 | 118,000 |
| 3 | 0.24% | 1.27% | 1,096,000 | 206,000 |
| 4 | 0.13% | 0.71% | 1,960,000 | 368,000 |
| 5 | 0.03% | 0.16% | 8,670,000 | 1,630,000 |

1. Proportion of the cohort in the ocean at the beginning of fishing exploitation on that age.

# 7 Evaluation of CWT Program; Conclusions and Recommendations

As illustrated in Chapter 5, uncertainty associated with estimates of ER can be minimized by increasing precision and/or accuracy. Precision can be improved either by improving estimates of total catch or escapement or by increasing the number of tagged fish recovered in samples of catch and escapement (i.e., increased tagging levels and/or sampling rates). Accuracy is best controlled through adherence to a rigorous sample design and through quality assurance and control. The workgroup has reviewed the tagging and sampling programs, the data collection, validation and reporting of agencies releasing and sampling tagged Chinook and coho salmon coastwide. This was accomplished through review of fishery sampling and indicator or regional tagging programs (Table 4-1 through Table 4-5). The basic standard for any estimation program is that estimated statistics should be unbiased and meet precision criteria. In our review, the precision guideline for estimates of tagged fish in harvest or escapement and estimates of ERs should have a PSE of 30% or less.

Workgroup members followed a general process to review the programs for Chinook and coho stocks and the fisheries which catch them, within each region as follows:

1. Quality Control
   a. Sample methods
   b. Data validation
   c. Data coordination and reporting
2. Quality assurance
   a. Stratification of fisheries and escapement areas
   b. Coverage of fisheries and escapement
   c. Sample expansion - estimation of total catch and escapement
   d. Sample rates
   e. Indicator stock coverage
   f. Number of tags released

The workgroup first used the information summarized for current tagging and sampling programs (Chapter 4), the criteria for precision and accuracy (Chapter 5), and expertise from workgroup members to develop a list of issues, with general consequences and solutions, affecting the quality of CWT data in the coastwide CWT system. A categorized list of problems and issues with tagging and sampling programs and with the estimates of the total harvest and escapement being sampled is in Section 7.1. Problems with data reporting and coordination that also impact the quality of the CWT data are listed in section 7.2. These lists cover most issues facing agencies and groups analyzing CWT data, for programs releasing and sampling CWTs, as well as estimating or forecasting population parameters such as harvest, escapement, total return, survival and ERs.

The issues discussed in Sections 7.1 and 7.2 have consequences generally resulting in greater imprecision in estimates or biased estimates of tagged harvest and escapement and of ERs. The problems can be remedied by changes in tagging, sampling, reporting, or release strategies. To

this end, workgroup members from each region reviewed their programs and identified both the issues and solutions that can be used to address specific problems, which appear in Sections 7.3 and 7.4. A compilation of issues, remedies, and costs are detailed in Appendix A by geographic region.

## *7.1 CWT Tagging and Sampling Issues*

The workgroup identified issues affecting the quality and reliability of CWT-based information and placed them into three general categories: (1) Tagging and Sampling specific to stock; (2) General sampling; and (3) Data reporting and coordination. The first two categories involve issues that affect statistical uncertainty surrounding CWT-based statistics, reflected by its two major components, precision and bias, and appear in this section. The third category involves the accuracy and completeness of CWT data reported for exchange and processes that are relied upon for timeliness, coordination, consistency, and accessibility; and is covered in Section 7.2. For each issue, problems and consequences are described and potential solutions are presented for consideration and discussion.

### 7.1.1 Tagging Issues

**ISSUE 1: Inconsistent and Incomplete Representation of Production Regions by CWT Indicator Stocks**

| Problem | Consequences | Solution |
|---|---|---|
| Important production regions are not represented by indicator stocks. Either the production is not represented, or inference is made from another (nearby) indicator stock without a means of validating the assumption of representativeness. | Lack of management information or potential bias in management statistics, impeding the ability to perform stock and fishery assessments to evaluate changes in migratory behavior or responses to particular environmental conditions (e.g., the 1983 El Nino).<br><br>Also an inability to monitor climate and production responses over time and areas. | For coho salmon, establishing a consistent, long-term indicator tagging program occurring simultaneously coast-wide would provide an extremely useful data source to detect and evaluate long-term trends. See Appendix D for a summary of coho salmon CWT groups currently used for regional representation.<br><br>For Chinook, adding indicator stocks for significant production groups that are not represented would provide for more complete representation of that production. |

**ISSUE 2: Determination of Tagging Levels**

| Problem | Consequences | Solution |
|---|---|---|
| Currently, CWT release levels are generally determined through the use of ad-hoc rules of thumb developed through limited analysis. There is no common method of determining tagged levels. | If release numbers are too low, too few CWTs will be recovered to achieve desired fishery resolution and precision in estimates of ERs.<br><br>If release numbers are too high, tagging and recovery costs are excessive. | Develop a standardized tool to assist managers in determining the tagging levels required to achieve a desired level of recovery stratification and precision. Use Bernard et al. (1998) as a guide. |

**ISSUE 3: Representation of Hatchery Production**

| Problem | Consequences | Solution |
|---|---|---|
| Hatchery production released without CWT group, which is becoming increasingly obvious with mass marking. | Stock composition of hatchery harvest cannot be estimated using current associated tagged releases. This does not allow estimation of hatchery programs' contribution to fisheries. Reduces the ability to estimate hatchery and wild abundances and fishery impacts. | All hatchery releases should have a representative tagged and clipped group. |

### 7.1.2 Terminal Fishery and Escapement Sampling Issues

**ISSUE 4: Low Sample Rates in Terminal Fisheries**

| Problem | Consequences | Solution |
|---|---|---|
| Low sample rates in terminal fisheries, resulting in few tags recovered. | Imprecise estimates of fishery impacts and cohort size, affecting uncertainty surrounding estimates of fishery ERs, survival, and may add uncertainty in preseason abundance forecasts used in fishery models. | Develop a standardized tool to assist managers in determining fishery sampling rates required to achieve a desired level of recovery stratification and precision where significant terminal fisheries occur and where outside stocks have been recovered in the past. |

**ISSUE 5: Low Sample Rates in Escapements**

| Problem | Consequences | Solution |
|---|---|---|
| Sample rates on spawning grounds are generally low or there is no sampling at all. | Low sampling rates reduce precision in estimates of tagged escapements and cohort size. No sampling underestimates cohort size causing survival to be biased low and ERs to be biased high, increasing uncertainty or adding bias to estimates of fishery ERs.<br>Creates uncertainty in preseason abundance forecasts used in fishery models. | CWT sampling of escapements should be of sufficient quality to achieve a desired level of recovery stratification and precision. Agencies should identify where tagged indicator stocks are expected to be present and develop adequate spawning grounds sampling programs in these areas.<br><br>Develop a standardized tool to assist management agencies in determining fishery escapement sampling rates appropriate for the indicator stock objectives. |

**ISSUE 6: Uncertainty in Estimates of Escapement or Terminal Fishery Catch**

| Problem | Consequences | Solution |
|---|---|---|
| Where the total catch or escapement being sampled is unknown, the sample expansion is also unknown. Tags are recovered without the ability to expand to total tags in catch or escapement. | Bias in estimates of total harvest or escapement leads to biased sample expansions and the estimate of tagged fish will be biased, introducing bias in estimates of cohort size and ERs. | Implement programs to develop unbiased and more precise estimates of total escapement and terminal fishery catch, where tagged fish are exploited or escape. |
| Where the total catch or escapement being sampled is estimated with low precision, the sample expansions are highly uncertain, so tags are expanded but the total numbers recovered are of low quality. | Reduced precision of the estimate of tagged fish in the harvest and escapement and of the estimates of cohort size and ERs.<br><br>Creates uncertainty in preseason abundance forecasts used in fishery models. | |

### 7.1.3 Sampling Issues for Highly Mixed Stock Fisheries

**ISSUE 7: Low Sample Rates in Highly Mixed Stock Fisheries**

| Problem | Consequences | Solution |
|---|---|---|
| Uncertainty in pre-terminal fishery impacts results when sample rates are low and few CWTs are recovered. | Fewer CWTs will be recovered; rare stocks may be missed resulting in imprecise or zero estimates of harvest and ER. This results in an inability to achieve adequate fishery resolution (lack of or insufficient tag recoveries) and imprecise estimates of ERs (low number of tag recoveries). | Develop a standardized tool to assist managers in determining fishery sampling rates required to achieve a desired level of recovery stratification and precision. Implement sampling programs as required to achieve desired levels of precision and accuracy. Bernard et al. (1998) is a helpful guide for this issue. |

**ISSUE 8. Uncertainty in Estimates of Catch in Highly Mixed Stock Fisheries**

| Problem | Consequences | Solution |
|---|---|---|
| Where the pre-terminal harvest being sampled is not known with certainty, the sample expansion is also uncertain, i.e., estimated.<br><br>For example, in commercial fisheries, catches are sometimes estimated using average weights; in sport fisheries, catches are estimated through creel census programs or punch card systems. | Reduced precision of the estimate of tagged fish in the harvest and of estimates of cohort size and ERs.<br><br>Bias in estimates of total harvest leads to biased sample expansions. Consequently, the estimate of tagged fish will be biased, introducing bias in estimates of cohort size and ERs. | Implement programs to obtain an unbiased estimate of total harvest with adequate precision in all pre-terminal fisheries. |

### 7.1.4 General Sampling Issues

**ISSUE 9: Non-representative Sampling**

| Problem | Consequences | Solution |
|---|---|---|
| Non-representative sampling can occur from a variety of practices. These include:<br>-combination of catches from time/area or gears, where stock composition is not homogenous and sample rates have not been equal over all time/area/gears within the combined strata<br>-disproportionate sampling of particular sizes or grades of salmon. | Estimates of the number of fish by tag code and ERs will be biased and, where this occurs, will affect most of the uses of CWT's in fishery management. | Design and implement representative sampling programs where not already in place. Communicate the rationale for representative sampling to stakeholders to increase options to collect representative samples. |

**ISSUE 10: Incomplete Coverage of Fisheries or Escapement Areas**

| Problem | Consequences | Solution |
|---|---|---|
| All fishery or escapement locations where tagged fish are present are not sampled. | Estimates of tagged fish are missing for unsampled fishery or escapement strata. Therefore, estimates of cohort size and ERs are biased, generally overestimated or zero. This could result in over fishing or in unnecessary fishery closures. | All locations where tagged fish for indicator or regional stock groups are present should be reviewed for importance to estimation of total cohort size. If presence of tagged fish is substantial these locations should be sampled. |

**ISSUE 11: Voluntary Sport Fishery Sampling Programs**

| Problem | Consequences | Solution |
|---|---|---|
| Under voluntary programs, the total number of CWTs caught in the sport fishery is estimated through the use of "awareness factors", or the proportion of adipose fin clipped fish returned voluntarily by anglers. Voluntarily returned CWTs are expanded by the awareness factor.<br><br>Several sport fisheries are not sampled for CWTs to estimate the awareness factor. Total recoveries are estimated assuming an awareness factor from another fishery or time period. | Various factors can cause bias in estimates derived from voluntary tag returns.<br><br>Anglers who return tags (volunteers) may not represent the fishing patterns of all anglers, resulting in some tag groups being overestimated and others underestimated.<br><br>There is no recovery of unmarked tags (i.e. from DIT groups or tagged supplementation programs).<br><br>Where awareness factors are not estimated directly from creel programs they must be assumed or estimated from other fisheries. This can introduce additional uncertainty and potential bias, especially when the origin of anglers varies between temporal and geographic strata.<br><br>This contributes unquantifiable | Evaluate options to produce representative, unbiased CWT recoveries from sport fisheries which rely upon voluntary returns of CWTs.<br><br>Implement direct sampling programs where significant recoveries of CWTs occur in order to collect, independent, random, and representative samples, e.g., creel census survey programs producing sampling rates of 20% or more.<br><br>Another option is to implement voluntary and direct recovery of CWTs to determine present, as potentially past, differences in CWT results from both methods. |

| | | |
|---|---|---|
| | imprecision and bias to estimated exploitation and survival rates for indicator stocks which are significantly impacted by fisheries that rely upon voluntary returns to recover CWTs.. | |

**ISSUE 12: Sampling Methods to Facilitate Mark Selective Fishery Evaluations and Processing of CWTs**

| Problem | Consequences | Solution |
|---|---|---|
| Tagged fish are currently sampled visually (looking for an adipose fin clip) or electronically (using a wand or tube detector).<br><br>Unmarked and tagged fish are not detected in visual sampling.<br><br>For some fisheries, CWTs from unmarked fish are collected but not processed.<br><br>Electronic sampling reduces the utility of using half tags to tag small wild fish trapped near spawning grounds | When visual sampling is employed or unmarked CWTd fish are not processed, CWTs of unmarked DIT fish will not be recovered. For Chinook salmon with multiple age return, this diminishes the ability of DIT to provide estimates of mark-selective fishery impacts on unmarked fish and potentially results in unproductive expenditures of tagging unmarked fish.<br>. | Implement electronic tag detection and processing of all fish with CWTs in all mark-selective fisheries. These stocks should be identified in mark-selective fishery proposals submitted to the PSC SFEC.<br><br>Agencies considering mark selective fisheries can review the CWT Expert Panel Report (2005) and PSC SFEC reports (e.g., 2002) to better understand strengths, weaknesses, and opportunities to use DIT methods to evaluate mark selective fisheries. |

## *7.2 Data Coordination and Reporting Issues*

The United States and Canada have established central data exchange points for each country. The U.S. exchange point is the Pacific States Marine Fisheries Commission's Regional Mark Processing Center (RMPC), which maintains the Regional Mark Information System (RMIS) a CWT database for all fish releases, all tag recoveries, and catch-sample information that originate in the U.S. The Canadian exchange point is the Pacific Biological Station, which maintains the Mark Recovery Program (MRP) CWT database for the Canadian Department of Fisheries and Oceans. Both RMIS and MRP maintain copies of the complete PSC CWT data set and have their own query and reporting systems.

The workgroup identified issues pertaining to timeliness and completeness of reporting, inter/intra agency data coordination, and data validation. The workgroup also identified issues relating to the need to clarify responsibilities and authorities for the RMPC.

**ISSUE 13: Timeliness of Reporting**

| Problem | Consequences | Solution |
|---|---|---|
| CWT data are not reported by all agencies by the dates in the established schedule for the PSC technical committees. Some agencies report their CWT recovery data two years after the fishery, even though CWTs have been processed, | Work of PSC technical committees cannot proceed on time to meet deadlines associated with cohort analyses of ERs of indicator stocks for fisheries conducted in the previous year. Often the committees must repeat analyses as new data are | Estimated recoveries from the previous year must be reported in time to plan fisheries for the current year, consistent with the August 13, 1985 Memorandum of Understanding between U.S.A. and Canada, Data Sharing section. |

| | | |
|---|---|---|
| because multi-agency agreement is needed to arrive at a post-season catch number. | added. Pre-fishery cohort abundance data are not available in time to forecast stock abundance for the upcoming year, so in the absence of timely CWT data, more uncertain assumption-based methods are relied on to forecast abundance of stocks. This affects the efficiency of the committees' work, results in confusion and misinterpretation of preliminary analyses, and impacts fisheries management decisions. | PSMFC should provide an annual report to the Commission regarding the performance of agencies in providing the data on the established schedule.<br><br>Require all reporting agencies to provide complete data in a timely manner for use in fisheries planning and management. |

**ISSUE 14. Incomplete/No exchange of CWT Data**

| Problem | Consequences | Solution |
|---|---|---|
| Not all data necessary to evaluate the integrity of the CWT data system are exchanged bi-laterally.<br><br>The catch/sample file does not include information on all fisheries and escapement locations where tagged fish are expected to be encountered. The information does not always include all data necessary to create sample expansion where sampling has occurred at the reporting level. Total catch or escapement information is not always reported where no sampling has occurred.<br><br>Reporting of total estimates of escapement and spawning ground recoveries is not consistent within and between agencies. Some agencies do not report recoveries from spawning ground surveys; some agencies report tag recoveries from escapement surveys or hatchery returns with no estimates of escapement and no sample expansion and this varies by species (i.e., coho vs. Chinook) and area.<br><br>Some data has not been reported at all, leaving data gaps for some stocks. | The catch-sample files are incomplete and PSC technical committee members are left to make personal contact with agency staff to acquire it. | The PSC Data Sharing committee and its subcommittee for Data Standards should assess and report on the options, implications, and impediments of managing these data, including the estimation of variance for estimated CWT recoveries and reporting of variances in the recovery file. This effort needs to be coordinated with the co-chairs of the CTC and CoTC. |

**ISSUE 15: Inter/Intra-agency Coordination**

| Problem | Consequences | Solution |
|---|---|---|
| Data collection and reporting processes involve several programs within or between agencies. A | When processes are not adequately coordinated, the resulting data can be incomplete, or missing, or | Promote better coordination of data collection needs within and among agencies to better meet regional |

| | | |
|---|---|---|
| failure to understand and appreciate the uses of CWT data may result in inadequate sampling methods or reporting of data.<br><br>Some agencies may have internal protocols that only require sampling and reporting of clipped and tagged fish without realizing the importance of unclipped and tagged DIT fish for evaluation of impacts of mark-selective fisheries. | unusable. This results in loss of tag information and biased estimates of statistics derived from CWT data. | needs. Non-technical communication materials can be used to educate others on the importance of the CWT programs. |

**ISSUE 16: Unclear Authority to Establish and Enforce Standards**

| Problem | Consequences | Solution |
|---|---|---|
| Within the PSMFC, the responsibilities and authorities for establishing and implementing standards, evaluating proposals that involve significant changes to RMIS, and prioritizing issues relating to reporting of CWT data are unclear. There is no funding to support coordination and implementation of standards and facilitation of coordinated data collection.<br>Lack of decision body to review and establish priorities with respect to formats and workloads for the RMPC staff on the CWT database. The RMPC's operations are overseen by the Mark Committee on Anadromous Fin Marking and Tagging. While PSC participants represent the major subset of the CWT user community served by the RMPC, the RMPC is, in effect, reporting to two organizational groups, the Mark Committee and the PSC. | The lack of a consistent and disciplined structure for coding systems impedes access and complicates analysis and accurate reporting of CWT data. | Convene two forums. The first would be between the analysts and data reporting staff within the agencies to engage in discussions of needs and possibilities for providing data needed. The second forum would be between analysts and the Data Standards to establish the standards for coding, validation of data, and develop specifications for report generation capabilities. |

**ISSUE 17: Updating CWT Data is Difficult and the Updates Cannot be Tracked**

| Problem | Consequences | Solution |
|---|---|---|
| Agencies update their data to make corrections and additions over time and the users of CWT data are often unaware that some of the data housed in RMIS have been updated and changed.<br><br>Correcting data is difficult and sometimes impossible. | Lack of a unique and stable ID for each recovery increases the difficulty of identifying sources of differences between sets of "identical" data retrieved at different times from RMIS. Experienced users learn to download data frequently to be sure they have the most recent datasets.<br>Known errors in historical data can | RMPC staff have made changes to the validation process and worked on data integrity issues independent of a formal system or committee to make recommendations for these changes. This may be adequate, but does not provide for input from all interested parties and may not catch all anomalies in the data.<br>Methods to easily correct individual |

| | | |
|---|---|---|
| | only be changed by uploading the entire data set from a reporting agency. This results in not correcting errors, especially for older data. | data need to be developed and tracked through time. |

### ISSUE 18: Validation is Inadequate for Current Uses of CWT Data

| Problem | Consequences | Solution |
|---|---|---|
| There is no formal system for establishing validation requirements and for acceptance of CWT data into regional databases. Examples:<br><br>a) Some fields are not checked for implausible values (e.g., lengths or catch sample expansion factors that are impossibly small or large).<br><br>b) Some fields are not cross checked (e.g., CWT code and species may not match release records; recovery records may not be tied to the correct catch sample records; double index tag groups may not be linked).<br><br>c) Some recoveries may be duplicated. | The responsibility for developing validation criteria falls on the RMPC. Errors that are not detected by the validation screening process are discovered by happenstance. The RMPC contacts agency coordinators requesting that corrective action be taken when errors are discovered. New validation rules are implemented when specific errors consistently re-occur.<br><br>Errors can unknowingly result when using CWT data. This can lead to: (a) decision-making based on erroneous information; (b) delays in the availability of time-sensitive data; (c) discrepancies in analysis of CWT data and confusion or controversy in interpretation; and (d) multiple re-analysis of data and explanation of discrepancies from previous results.<br><br>PSC technical committees and other users of CWT data must often develop their own validation or screening methods to minimize the potential for inappropriate data to be incorporated into their analyses.<br><br>Validation does not include many fields that are important to analysis of CWT data, in particular new fields due to mass marking and double index tagging. | Establish a mechanism to establish, revise, and enforce validation rules for CWT data.<br><br>This could be solved by designating a group to review validation criteria and to add and develop new validation rules as needed. Members would need the expertise and experience required to implement such an approach. |
| With the introduction of MM and MSF it became necessary to add additional fields to the RMIS databases (catch-sample, release and recovery). These fields are not consistently reported to the database and there is no validation in place for any of these fields. | Analysis of CWT data with MM and MSF requires that analysts use these new fields, but as they are not consistently reported, analyses can be difficult or impossible to accomplish. | Recommendations should be developed to add validation algorithms for some of these fields as recommended by the workgroup described above. |

### ISSUE 19: Lack of Formal Designation of RMPC as the Official U.S. Public Database and Lack of Adequate Funding Support

| Problem | Consequences | Solution |
|---|---|---|
| Lack of stable funding to support PSC data exchange functions and responsibilities of the PSMFC Mark Center. | Lack of funding will result in the inability of the RMPC to provide timely quality data for the region. | Provide stable bilateral funding to establish the RMPC as the U.S. coast-wide repository of hatchery release, CWT, and catch-effort data |

| | | |
|---|---|---|
| The availability of funding to support implementation of standards and facilitation of coordinated data collection is uncertain. | No assurance of continuity.<br><br>Potential duplication of effort and unproductive expenditures. | accessible to fishery scientists and the public.<br>Conduct a feasibility study on changing the systems functionality including an audit of current expenditures and cost forecasts of different systems such as distributed rather than centralized data processing and warehousing. |

## *7.3 Regional Priorities for Improving the Quality of CWT Data*

Workgroup members from each region identified priorities for improving CWT data for the stocks and fisheries within their respective jurisdictions using the results from Chapters 4, 5, and sections 7.1 and 7.2. Workgroup recommendations for measures which offer the greatest promise for improving the quality of CWT data for each issue and jurisdiction are presented in this section with priorities set by the regional members of the workgroup. Priorities are presented in three categories (high, medium, and low). Agency rationales for priority assignments for each issue are summarized in the following tables. Detailed information describing and supporting the priorities, and, where available, estimated costs of implementation, is provided in Appendix A.

**ISSUE 1: Inconsistent and Incomplete Representation of Production Regions**

| | **Chinook** | | **Coho** | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | High | Chinook - Establish the Taku, Unuk and Chilkat stocks as formal ER Chinook indicator stocks. Second, include these as Model Stocks for the PSC Chinook Model at such time this is agreed and feasible. | High | A coho CWT tagging and adult escapement program should continue to be funded on the Chickamin River, which represents another life history and exploitation pattern present in the southern inside area of SEAK. A coho escapement program should be funded for 3-5 years on the Stikine River. |
| British Columbia | High | Some indicator programs can be functional almost immediately if funding was available for escapement programs (Lower Shuswap, Nicola, Atnarko). Additional funding is needed to develop indicators for Upper Fraser River springs and summers, and Strait of Georgia Mainland. | High | Funding is required to develop indicator programs to represent each production region. Indicator programs will be reviewed under implementation of the Wild Salmon Policy. Indicator programs are necessary for both the Southern and Northern Boundary coho PST agreements. |
| Washington (excluding Columbia River) | High | Establish indicator stocks for Grays Harbor and Willapa fall Chinook. The need to establish CWT indicators for stocks that are not significantly harvested by ocean fisheries (e.g., several spring stocks) should be reviewed. | Medium | Further analyses by the CoTC are needed to determine if additional wild stock tagging or DIT programs within the region are necessary. For example, wild stock tagging programs may be proposed for the Stillaguamish and Hoh River |

| | | | | |
|---|---|---|---|---|
| | High | Review the distribution of DIT stocks | | MUs if the current surrogate MUs used to assess survival and fishery impacts for these stocks are considered inadequate. |
| Columbia River | Medium | Establish wild stock tagging program where feasible. Where MM and MSF have potential significant impacts, additional coverage of DIT groups may be called for. Lower River origin tagged releases would need to be expanded to provide adequate representation of lower river wild stocks. | Low | Establish wild stock tagging program where feasible. |
| Oregon (excluding Columbia River) | High | Elevate Elk River to proper position as ER stock, development of Mid Oregon Coast indicator. | Low | Coho production facilities on the Oregon coast have been re-vamped in the recent past with agency prioritization on natural production groups over supplementation programs. |
| California | High | Develop hatchery surrogates to represent wild Chinook stock population parameters. | | |
| | Medium | Develop marking strategies in hatcheries that would mimic the life history of the wild Chinook stocks ( Yuba River& Upper Sac) | | |
| | High | Increase the percentage of fall-run production marked at Iron Gate hatchery to a constant fraction (~25%) | | |

## ISSUE 2: Determination of Tagging Levels

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | High | Capture methodologies and effort have been increased to CWT > 40K smolt in 2005-2006 on the Stikine River, to levels that will produce population statistics with adequate levels of precision and accuracy. | | |
| British Columbia | Medium to High | Tagging levels for existing and new indicator stocks should be adjusted to consider expectations for survival variation and fishery and escapement sampling rates to produce desired precision for stock parameters. | Medium | Tagging targets should be adjusted to consider expectations for survival and fishery and escapement sampling rates to produce a desired precision for stock parameters. DIT coverage for existing programs will be reviewed. Establishment of adequate indicator stock coverage is the first priority. |

| | | | | |
|---|---|---|---|---|
| Washington (excluding Columbia River) | | | High | Recent survival rates, fishery ER, and sampling rates need to be reviewed. Given these rates, current tagging levels should be adjusted to produce a desired precision for ER and survival rate estimates. |
| Columbia River | High | Additional resources for tributary sampling for Chinook salmon. | High | Additional resources for tributary sampling for coho salmon. |
| Oregon (excluding Columbia River) | Medium | Confine release group(s) within narrow geographic range. Confine both DIT and SIT releases to one hatchery or co-location. | Low | Required tagging release group sizes on Oregon coast are inconsistent with concurrent ESA listed stock's needs. |
| California | High | Lack of technical oversight and review of estimation methodologies. | Low | No directed take of coho in California allowed. |

**ISSUE 3: Representation of Hatchery Production**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| California | High | Increase production tagging at Iron Gate in the Klamath and continue CFM in the Central Valley started in 2006 | | |
| Workgroup | | | High | For coho salmon a consistent, long-term indicator tagging program occurring simultaneously coast-wide can provide an extremely useful data source to detect and evaluate long-term trends. Without an indicator stock program which involves the consistent release of CWTs to represent important coho MUs, it is difficult to determine whether salmon have changed their migratory behavior over time, or how they're responding to particular conditions (e.g., the 1983 El Nino). |

**ISSUE 4: Sampling Rates in Terminal Fisheries**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | Medium | Historical CWT sampling showed that terminal commercial fisheries were comprised primarily of Alaskan hatchery fish. These fisheries should be sampled again to verify that stock composition has not changed. | Medium | Historical CWT sampling showed that terminal commercial fisheries were comprised primarily of Alaskan hatchery fish. These fisheries should be sampled again to verify that stock composition has not changed. |

| | | | | |
|---|---|---|---|---|
| British Columbia | Medium to High | Terminal Native fisheries should be sampled to produce statistically valid and representative CWT recoveries. Agreements to sample and expand CWTs must be obtained and plans for random and representative sampling implemented.<br>Similarly, sampling of terminal recreational fisheries may be important for certain indicator stocks. | Low to Medium | Comments similar to Chinook but terminal Native and recreational fisheries tend to be less important to the existing Coho indicator stocks. This situation could vary with other indicators, particularly in the presence of mass-mark selective fishing.<br>These terminal fisheries tend to be a relatively small component of the total fishing mortalities on these stocks. |
| Washington (excluding Columbia River) | Medium to High | Implement sampling programs for freshwater sport fisheries occurring in watersheds with ER indicator stocks, where feasible and cost-effective. Alternative approach, particularly applicable in situations of low catch rates is to devise methods for indirect estimation (e.g., apply nearby net fishery or hatchery sampling information to catch estimates). See Appendix A for more detail on individual systems. | High | Implement sampling programs for freshwater sport fisheries occurring in watersheds with ER indicator stocks, where feasible and cost-effective. Alternative approach, particularly applicable in situations of low catch rates is to devise methods for indirect estimation (e.g., apply nearby net fishery or hatchery sampling information to catch estimates). See Appendix A for more detail on individual systems. |
| Columbia River | Medium | Areas of low sampling coverage have been identified and ODFW is currently seeking funding to address those that have been identified. Additional resources needed to improve sampling rate. | Low | Terminal sport catch of coho has historically been low, apart from the Buoy 10 fishery. Additional resources needed to improve sampling rate. |
| Oregon (excluding Columbia River) | Medium | Terminal fishery sampling is more comprehensive in smaller area basins than in more geographically dispersed fisheries. | Low | There has historically been a low level of terminally caught coho. |
| California | High | Incomplete sampling of coastal recreational fisheries, upper Klamath and Trinity | Low | No reporting of Tribal harvest |

## ISSUE 5: Sampling Rates in Escapements

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | Low to Medium | For indicator stocks, the estimated escapements and sample rates follow a study design intended to produce the desired precision for indicator stock parameters. | Low to Medium | Same comment for indicator stocks but inadequate coverage of production regions by indicator stocks. |
| Washington (excluding Columbia River) | High | Chinook escapement is generally sampled to some degree in systems with tagged indicator stocks. However, the programs need to be reviewed with reference to | High | Escapement survey programs should be reviewed (see below for total estimation) and sample programs instituted where tagged stocks (particularly DIT) are present. Coho escapement in coastal systems are |

| | | | | |
|---|---|---|---|---|
| | | achieving precision goals and spawning distributions. See Appendix A for more detail on individual systems. | | sampled at some level. These should be reviewed and sample designs adjusted where necessary to achieve precision objectives. Coho escapement in Hood Canal is sampled, but no expansions are available by individual river basins. The escapement estimation method should be stratified to supply estimates of total escapement where tagged fish are recovered. |
| Columbia River | Medium | As listed populations become drivers for North of Falcon fisheries, both accurate and precise escapement estimations of Columbia River Tributaries will be required. Some tributaries escapements are not sampled at standard rate. Additional resources would improve sampling rates. | Low-Medium | Escapement sampling is currently occurring to meet management objectives at ESU levels Some tributaries escapements are not sampled at standard rate. Additional resources would improve sampling rates. |
| Oregon (excluding Columbia River) | Medium | Escapement sampling programs in smaller indicator streams are currently more comprehensive than those found in larger systems. | Low | Escapement sampling is currently occurring to meet management objectives at ESU levels |
| California | Medium | Escapement sampling in coastal streams is inconsistent. | Low | Escapement sampling in coastal streams is inconsistent. |

**ISSUE 6: Uncertainty in Estimates of Escapement or Terminal Fishery Catch**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | Low | Existing indicator stock programs have adequate coverage and accurately estimate escapement. | Low | Existing indicator stock programs to accurately estimate escapement have adequate coverage, but the coverage of indicator stocks is acknowledged to be inadequate. |
| | High | Opportunities exist to implement new mark-recapture programs for indicator stocks identified above in Issue 1. All other facets of the indicator program are already in place. | | |
| Washington (excluding Columbia River) | High | Escapement estimation in Puget Sound and WA coast for Chinook salmon is carried out using various methods. These need to be reviewed on a watershed basis and the sample designs evaluated. See Appendix A for further details. | High | Coho escapement in Puget Sound is estimated using expansions from index area to total river. The expansions used were estimated using mark-recapture; complete surveys or biologists best information anywhere from 15-30 years ago. The escapement estimation requires a complete evaluation and redesign for coho. See Appendix A for further |

| | | | | |
|---|---|---|---|---|
| | | | | details |
| Columbia River | Medium | As listed populations become drivers for North of Falcon fisheries, both accurate and precise escapement estimations of Columbia River Tributaries will be required. Escapement estimates for some tributaries rely on post-season run reconstruction rather than direct observation. Provide additional resources for direct observation. | Medium | ODFW is currently targeting 8 TRT populations to provide overall wild abundance in Columbia River Tributaries. Will recover carcasses and CWTs from those sampled. Expansion factors have historically not been calculated. Newly designed spawning surveys should be able to provide CWT expansions. Escapement estimates for some tributaries rely on post-season run reconstruction rather than direct observation. Provide additional resources for direct observation. |
| Oregon (excluding Columbia River) | Medium | The need for additional escapement sampling in larger systems has been identified and will be pursued in relation to concurrent regional objectives | Medium | The need for additional escapement sampling in larger systems has been identified and will be pursued in relation to concurrent regional objectives |
| California | Low | Implement counting weirs to measure bias in specific Chinook salmon surveys. (Upper Sac, Feather River) | Low | Implement counting weirs to measure bias in specific coho salmon spawning surveys. |
| | Medium | Develop agency oversight on funding priorities to improve the consistency of escapement monitoring | Medium | Develop agency oversight on funding priorities to improve the consistency and coverage of coastal stream escapement monitoring and Central Valley and coastal recreational inland fisheries |

## ISSUE 7: Sampling Rates in Highly Mixed Stock Fisheries

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | Medium | Raise sampling rates in commercial purse seine and assure temporal representation in commercial net fisheries. Raise the sampling rates for the Petersburg and Wrangell area sport fisheries. | Medium | Raise sampling rates in commercial purse seine and assure temporal representation in commercial net fisheries. |
| British Columbia | Low to Medium | Sport fishery sample rates are generally low. Improved communication of voluntary head recovery program may improve sampling rates by increasing awareness. Few sampling programs exist for native fisheries in ocean waters, and main gaps are on WCVI and QCI. | Low to Medium | Sport fishery sample rates are generally extremely low and much lower than for Chinook. Improved communication of voluntary head recovery program may improve sampling rates by increasing awareness. |
| Washington (excluding Columbia | | Review fisheries with low sample rates or no sampling | | |

| | | | | |
|---|---|---|---|---|
| River) | | with reference to presence of tagged stocks. | | |
| Columbia River | Low | Additional resources for sampling in certain fisheries. | Low | Additional resources for sampling in certain fisheries. |
| Oregon (excluding Columbia River) | Low | All pre-terminal fisheries have historically been adequately sampled. | Low | All pre-terminal fisheries have historically been adequately sampled. |
| California | Low | All pre-terminal fisheries have historically been adequately sampled. | Low | All pre-terminal fisheries have historically been adequately sampled. |

### ISSUE 8. Uncertainty in Estimates of Catch in Highly Mixed Stock Fisheries

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | Medium to High | Catch is not estimated for all time periods or areas of the sport or Native fisheries where significant catch of indicator stocks may occur. Estimates of precision are adequate. | Medium to High | Catch is not estimated for all time periods or areas of the sport or Native fisheries. Estimates of precision are adequate. Other priority activities above are more important. |
| Washington (excluding Columbia River) | Medium | Implement routine evaluations of potential bias with commercial and sport fisheries catch estimation programs (e.g. over the bank sales, egg sales, recent Skokomish River sport and Skokomish River tribal net evaluations) on systematic basis prioritizing highest impact fisheries. | | |
| Columbia River | Low | The value of quantifying the uncertainty of catch estimates is yet to be determined. | Low | The value of quantifying the uncertainty of catch estimates is yet to be determined. |
| Oregon (excluding Columbia River) | Low | The value of quantifying the uncertainty of catch estimates is yet to be determined. | Low | The value of quantifying the uncertainty of catch estimates is yet to be determined. |
| California | Medium-low | Quantify the uncertainty of the ocean sport fisheries private access catch.<br>Quantify the Bias in unreported landings and avoidance of sampling in the troll fishery. | | |

## ISSUE 9: Non-representative Sampling

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | Medium | Implement safeguards to ensure temporal sampling coverage in commercial purse seine and drift gillnet fisheries. | Medium | Implement safeguards to ensure temporal sampling coverage in commercial purse seine and drift gillnet fisheries. |
| British Columbia | Medium to High | In addition to comments in above tables, this problem has been recognized and steps have been taken to coordinate the creel survey study designs with the regulation stratification. Additional research is needed to assess issues associated with non-representative sampling. (e.g., implications of limiting creel survey sampling sites to public access sites, while excluding private marinas which may be frequently used by charter boats and guides, who may have higher CPUEs). Improvements to the sport logbook program are needed to improve catch data, CWT recovery, and improve cooperation from more lodges and charter operations. | Medium to High | Same comment as Chinook |
| Washington (excluding Columbia River) | | Increase sampling staff to cover fisheries with broad geographic span and to account for over-bank, egging and non-commercial catches. | | Increase sampling staff to cover fisheries with broad geographic span and to account for over-bank, egging and non-commercial catches. |
| Columbia River | High | The need to provide overview of state's sampling programs has been recognized and is being addressed. | High | The need to provide overview of state's sampling programs has been recognized and is being addressed. |
| Oregon (excluding Columbia River) | High | The need to provide overview of state's sampling programs has been recognized and is being addressed. | High | The need to provide overview of state's sampling programs has been recognized and is being addressed. |
| California | High | Management needs finer detailed catch/area stock composition. | | |
| | High | Improve enforcement of trollers identifying block/area of catch. Seek regulations to enforce trollers to separate catch into management areas | | |
| | Medium | Full GSI/CWT sampling along with Satellite Vessel Monitoring system of trollers. Catch and effort | | |

**ISSUE 10. Incomplete Sampling Coverage for Fisheries and Escapement**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | Low to Medium | Unsampled commercial fisheries are small and past sampling indicated few, if any, indicator stock CWTs. Some sport and Native fisheries are unsampled. | Low to Medium | Same comment as Chinook. |
| Columbia River | High | Increase sampling of summer sport fisheries in the Columbia River given appropriate funding. | Low | Escapement sampling is currently occurring to meet management objectives at ESU levels. Additional funding would be needed to implement directed fishery sampling programs beyond those that are currently prosecuted |
| | High | Modify sampling in lower Columbia River to allow for recoveries of DIT fish | | |
| | High | Equip samplers with appropriate gear to collect tags in escapement. | | |
| Oregon (excluding Columbia River) | Medium | Additional funding will be needed to implement programs beyond those that are currently prosecuted. | Low | Escapement sampling is currently occurring to meet management objectives at ESU levels. Additional funding would be needed to implement directed fishery sampling programs beyond those that are currently prosecuted. |
| California | Medium | Incomplete sampling of CA coastal inland recreational Chinook salmon fisheries. | Medium-Low | Develop agency oversight on funding priorities to implement coastal monitoring plan including escapement monitoring. |
| | Medium | Develop agency oversight on funding priorities to improve the coverage of escapement monitoring. | | |

**ISSUE 11: Voluntary Sampling Programs**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | High | Studies are needed to determine the degree of bias in the distribution of observed CWTs. The study would help plan opportunities to improve CWT data from the sport fisheries. Improvements to voluntary recovery program, and/or direct sampling of sport fisheries are needed to improve awareness and reduce bias. | High | Same comment as for Chinook. |

**ISSUE 12: Sampling Methods and Processing CWTs**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| Alaska | Low | Do nothing or institute electronic tagging, that is not fiscally or logistically feasible. Analytically must make assumption that the ERs of clipped and unclipped DIT groups | | |

| | | | | |
|---|---|---|---|---|
| | | are the same. | | |
| British Columbia | Low to Medium (medium for US agencies) | Reallocation of resources to sample unmarked CWTs could occur after canceling other stock assessment or fishery monitoring programs. Cost will be determined by the extent of electronic sampling. If restricted to major mixed stock commercial fisheries, costs will be modest (note that this is the estimated cost in Appendix A). If such sampling is expanded to all fisheries, the cost will increase significantly and perhaps double the current investment into sport fishery programs.<br><br>The extent of catch estimation, sampling, and awareness needs to be reviewed across all Canadian sport fisheries. The tools used to estimate the total number of CWTs harvested will depend on funding. Options include additional creel surveys, improvements to study designs of current creel surveys, use of other survey instruments. | Low to Medium (medium for US agencies) | Same comment, likely greater priority than Chinook due to implementation of DIT tagging programs. |
| Oregon (excluding Columbia River) | Low | There is no need to modify sampling programs unless there are MSFs impacting Oregon fall Chinook, or if there is the need to reduce processing costs. | Low | Allocation of resources to examine the contribution of unmarked catch competes with alternate agency priorities. |
| California | High | Seek additional funding to increase staffing and recovery efforts associated with Central Valley Fall-run constant fractional marking that began in 2006. | | |

## *7.4 Regional Priorities for Improving Data Coordination and Validation*

**ISSUE 13: Timeliness of Reporting**

| | **Chinook** | | **Coho** | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | High | Several indicator stocks (including those for stocks of conservation concern) are caught in southern U.S. fisheries, but those CWT recoveries are not reported bilaterally until two years after the fishery. Those CWT recoveries are extremely valuable to plan fisheries for the current year, prepare stock abundance forecasts, assess stock status, and evaluate previous year's fishery and PST performance (e.g. ISBM indices). | High | Same as Chinook. |
| California | High | Develop agency oversight to improve inconsistent reporting and coordination on state wide CWT releases and recoveries. | | |

**ISSUE 15: Inter/Intra-agency Coordination**

| | Chinook | | Coho | |
|---|---|---|---|---|
| **Region** | **Priority** | **Solution** | **Priority** | **Solution** |
| British Columbia | Medium | Bilateral coordination of ocean sampling program designs, objectives, and rationale are needed to establish clear PST-driven priorities and advice. Otherwise domestic program planning will continue to evaluate PST and domestic priorities and allocate available funding to highest priority activities. | Medium | Same comment as for Chinook. |
| California | Medium | Develop agency oversight to improve the consistency and timeliness of inland recovery reporting. | Medium | Develop agency oversight to improve the consistency and timeliness of inland recovery reporting. |

## 7.5 *Summary*

The Expert Panel stated in their report (Hankin et.al. 2005) that "…it will be important to maintain a reliable CWT system during the transition period to ensure data continuity and to allow evaluation of the relative performance of some new technology or approach as compared to the CWT system" and the first three recommendations were intended to "correct deficiencies in data collection and reporting throughout the basic CWT system and to improve analysis of CWT recovery data". The CWT workgroup therefore focused its efforts on reviewing the current status of the CWT system with reference to the quality of the sampling and data collection, to the data validation and reporting (Chapter 4) and also reviewed the status of the data with respect to precision and accuracy of estimates derived from CWT data (Chapter 5).

The CWT workgroup developed a categorized list of issues that impact the quality of the CWT data and estimates derived from CWT data (Section 7.1 and 7.2). Workgroup members from each region reviewed their tagging, sampling, and data reporting programs with the assistance of agency staff. Actions and priorities to problems identified in this review are listed by region in Sections 7.3 and 7.4 and Appendix A.

The CWT workgroup recommends that agencies implement these solutions with reference to the priorities identified. The CWT workgroup recommends that the PSC and agencies take action on several recommendations described below:

1. The workgroup identified gaps in geographic and stock type tag representation (Section 7.1 and 7.3) which should be addressed by the PSC and agencies. Coho coverage. There is no formal coho coast-wide indicator stock program, but all tagged releases are used where appropriate. Consequently some regions are adequately represented and others have no or few tag recoveries (See Appendix D).
2. The PSC should focus additional consideration of uncertainty in determining tagging and sampling levels. Agencies and/or the CTC and CoTC should undertake evaluation of all Chinook indicator stocks and all tagged groups from coho regional grouping from the perspective of the uncertainty inherent in estimates of ER. For any indicator stock or tag group of interest the following must be in place:

a. All fisheries and escapement locations should be sampled directly, ensuring unbiased estimates of ER for the tag group (Section 5.3 and Chapter 7).
b. A minimum of 10 tags per fishery stratum is required to provide estimates of ER that are of minimally sufficient precision (which provides a 95% confidence interval no larger than ±60% of the estimate or a PSE of 30% – Section 5.3).
a. In order to achieve the minimum number of tags recovered in fisheries and escapement, sample rates and/or tag release group size should be evaluated using the tool described in Chapter 6.

3. In some cases tagged hatchery fish stray to the spawning grounds, where sampling should occur to provide unbiased estimates of ER. However review of the sampling programs (Tables 4.2 and 4.3) indicate that spawning ground sampling is often not in place. In addition, estimates of escapement to the spawning grounds, and the associated expansion factors for CWTs, are often uncertain, and possibly biased. Agencies should evaluate their escapement estimation and sampling programs where tagged Chinook and coho groups are present.
4. Sampling methods must provide representative samples of all tagged fish (marked and unmarked) in the fishery or in escapement (Section 7.1.4), where applicable. Agencies should evaluate their sampling programs with this in mind.
5. The advent of mass marking and mark-selective fisheries has had an adverse impact on sampling methods and data reporting by agencies. Addition of new fields to the CWT data system due to MM and MSF has complicated use of the data for CoTC and CTC analyses. It is necessary that agencies use appropriate sample methods and data reporting to assure that data quality are maintained.
    a. Agencies should evaluate their sampling programs with reference to requirements now in place. Reporting of sample method (electronic vs. visual), fishery type (selective vs. non selective), tag group type (DIT vs. non-DIT), and mark status in release and recovery files are new data fields and are not consistently reported. Also, the reporting of the tag/mark status in catch-sample file has become more complicated and agencies should review their procedures.
    b. The CWT workgroup recommends that a workgroup including members of the CoTC and CTC should be charged to review the current validation process in reporting data to RMIS and provide recommendations on what additional validation procedures should be instituted (Section 7.2 and 7.4).

## References


ASFEC (Ad-hoc Selective Fisheries Evaluation Committee). 1995. Pacific Salmon Commission mark-selective fishery evaluation. Pacific Salmon Commission, Vancouver, BC, Canada.

Bernard, D. R., and J. E. Clark. 1996. Estimating salmon harvest based on return of coded-wire tags. Canadian Journal of Fisheries and Aquatic Sciences 53:2323-2332.

Bernard, D.R., R.P. Marshall and J.E. Clark. 1998. Planning programs to estimate salmon harvest with CWTs. Can. J. Fish. Aquat. Sci. 55: 1983-1995.

Bowhay C. 2003. Implications of Legislative Directives to Mass Mark. In: Future of the CWT Program: Challenges and Options. A Workshop June 7-10, 2004

Chilcote, M., T. Nickelson, and K. Moore. 2005. Oregon Coastal Coho Assessment Part 2: Viability Criteria and Status Assessment of Oregon Coastal Coho. Oregon Department of Fish and Wildlife, Salem, Oregon.

CTC (Chinook Technical Committee). 2001. Pacific Salmon Commission Joint Chinook Technical Committee Report Annual ER Analysis and Model Calibration. Report TCCHINOOK (01)-2. Pacific Salmon Commission, Vancouver, BC, Canada. 177 p.

CTC (Chinook Technical Committee). 2005. Pacific Salmon Commission Joint Chinook Technical Committee Report Annual Exploitation Rate Analysis and Model Calibration. Report TCCHINOOK (05)-3. Pacific Salmon Commission, Vancouver, BC, Canada. 232 p.

DFO. 2002. Interior Fraser River Coho Salmon. DFO Science Stock Status Report. D6-08 (2002).

DSWG (Data Standards Workgroup). 2005. Specifications and definitions for the exchange of coded wire tage data for the North American Pacific Coast. PSC Format Version 4.0. Pacific Salmon Commission, Data Standards Work Group; December 16, 2005. www.rmpc.org/files/PSC_V40_Specification.pdf.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commerce, NOAA Technical Memorandum. NMFS-NWFSC-66, 598 p.

Hankin, D.G., J.H. Clark, R.B. Deriso, J.C. Garza, G.S. Morishima, B.E. Riddell, C. Schwarz, and J.B. Scott. 2005. Report of the Expert Panel on the Future of the Coded Wire Tag Program for Pacific Salmon. PSC Tech. Rep. No. 18, November 2005. 300 p (includes agency responses as appendices).

Hayman, B. 2007. Hatchery vs. wild CWT distribution for Puget Sound and Washington coastal coho. PSC Southern Fund 2007 Funded Proposal. Skagit River System Cooperative, La Conner, WA.

Jefferts, K. B., P. K. Bergman, and H. F. Fiscus. 1963. A coded wire identification system for micro-organisms. Nature (London) 198:460-462.

Johnson, K. 2004. Regional review of CWTging of anadromous salmon and steelhead in northwest America. Paper updated from 1989 to current year 2004.

Jones, E. L. III, D. R. Bernard, S. A. McPherson and I. M. Boyce. 2006. Production of coho salmon from the Taku River, 1999-2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-02, Anchorage, Alaska.

McPherson, S. A., D. R. Bernard, and S. T. Elliott. 1994. Production of coho salmon from the Taku River, 1992-1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-38, Anchorage, Alaska.

McPherson, S. A. and D. R. Bernard. 1995. Production of coho salmon from the Taku River, 1993-1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-29, Anchorage, Alaska.

McPherson, S. A. and D. R. Bernard. 1996. Production of coho salmon from the Taku River, 1994–1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-25, Anchorage, Alaska.

Morishima, G.S. 1986. Minutes of Pacific Salmon Treaty CWT-indicator stock workshop. Unpublished memorandum.

Olson, R., J. Gutmann, and K. Phillipson. 1997. Review of Tribal CWT indicator stocks. Northwest Indian Fisheries Commission.

Parken, C. K., R. E, Bailey, and J. R. Irvine. 2002. Incorporating uncertainty into area-under-the-curve and peak count salmon escapement estimation. North American Journal of Fisheries Management 23:78-90.

PSC (Pacific Salmon Commission). 2004. Pacific Salmon Treaty. PSC, Vancouver, BC.

Riddell, B. 2004. Pacific Salmon Resources in Central and North Coast British Columbia. Pacific Fisheries Resource Conservation Council, Vancouver, BC, Canada.

Scott, J.B, S.D. Moore, and R.A. Moore. 1992. Review of the Chinook exploitation rate indicator stock program for the Washington Coast and Puget Sound. Northwest Indian Fisheries Commission and Washington Department of Fish and Wildlife.

SFEC (Selective Fishery Evaluation Committee). 2002. Investigations of methods to estimate mortalities of unmarked salmon in mark-selective fisheries through the use od double index tag groups. SFEC (02)-1. Pacific Salmon Commission, Vancouver, BC, Canada.

TCDS (Technical Committee on Data Sharing). 1989. Joint Technical Committee on Data Sharing, Joint Working Group on Mark Recovery Databases, Information content and data standards for a coastwide coded-wire tag database. TCDS (89)-1. Pacific Salmon Commission, Vancouver, BC, Canada.

Zhou, S. 2000. Stock Assessment and Optimal Escapement of Coho Salmon in Three Oregon Coastal Lakes. Information Report. Fish Division, Oregon Department of Fish and Wildlife, Portland, Oregon.

# Appendix A. Regional Reports on Issues with CWT System

Workgroup members from each region identified priorities for improving CWT data for the stocks and fisheries within their respective jurisdictions using the results from Chapters 4 and 5. This Appendix provides detail on the problems, identifies their consequences, provides the solutions recommended by the workgroup and, where possible, gives a preliminary estimate of the cost. The solution sections provided here are also outlined in section 7.3 where the workgroup members have also assigned a priority as recommended by the members from each region. The issues below are organized as described in sections 7.1 and 7.2.

## *Alaska Chinook*

**Tagging Issues**

1. Low tagging rate on wild stock with no hatchery surrogate.
   - i. Problem: Stikine River (TBR system) wild Chinook have had low smolt tagging levels until 2005.
   - ii. Consequence: Run reconstruction, parameter estimates, and abundance-based management will be less precise than desired by technical committee data standards.
   - iii. Solution: Capture methodologies and effort have been increased to CWT > 40K smolts through funding from the PSC Northern Endowment Fund and PCSRF.
   - iv. Cost: $100,000 annually

2. Chinook stocks not represented by CWT data in the CTC analysis for the PSC.
   - i. Problem: Five SEAK/TBR stocks are not represented by CWT data in CTC work at present—Taku (TBR), Stikine (TBR), Alsek (TBR), Chilkat, and Situk Rivers. One other, the Unuk River, is likely poorly represented in the PSC Chinook Model by the ASI stock. The Alsek and Situk River stocks are not an issue because almost all harvest occurs in terminal areas (in river or in river mouths).
   - ii. Consequence: Incomplete representation of these spring yearling stocks in the PSC Chinook Model. Additionally, the ERs, survival, and distributional data are not tracked by the CTC.
   - iii. Solution: Two-fold. First, establish the Taku, Unuk, and Chilkat stocks as formal ER indicator stocks for the CTC. Second, consider including these as Model Stocks for the PSC Chinook Model if deemed necessary and beneficial.

**Sampling Issues**

3. Low sampling rate in the purse seine fishery.
   - i. Problem: The sampling rate in the traditional commercial purse seine fishery is low (about 15%), which drops the overall SEAK net sampling rate to slightly below 20% (19.7%), on average for the past five years.
   - ii. Consequence: Precision of estimates of ERs, etc, for some PSC indicator stocks present in low numbers will be less than desired by technical committee data standards.
   - iii. Solution: Raise sampling rates in total and assure temporal representation.

iv. Cost: $30,000 annually.

4. Low sampling rate in terminal commercial fisheries.
   i. Problem: The sampling rate in most terminal commercial fisheries is low (5-10%). When these fisheries were developed in the 1980s, sampling rates were above 20% and indicated that these harvests are almost all of Alaska-hatchery origin.
   ii. Consequence: Precision of estimates of ERs, etc, for some PSC indicator stocks present in low numbers will be less than desired by technical committee data standards.
   iii. Solution: Consider annual spot-checking (raising sampling in selected fisheries to above 20%) to verify historical results.
   iv. Cost: $25,000 annually.

5. Low sampling rate in sport fishery.
   i. Problem: The sampling rate in the SEAK sport fishery is slightly below 20%.
   ii. Consequence: Precision of estimates of ERs, etc, for three PSC indicator stocks (SEAK, Kitsumkalum, and Queets) will be less than desired by technical committee data standards.
   iii. Solution: Provide funding to staff dedicated solely to catch sampling across ports in SEAK to raise the sampling rate above 20% and increase precision of statistics used by the CTC.
   iv. Cost: $40,000 annually.

6. Alaska employs visual sampling, not electronic.
   i. Alaska has produced high-quality CWT data since 1981 using visual sampling for CWTs and will continue to do so into the foreseeable future.

## *Alaska Coho*

### Tagging Issues

7. Low stock representation for coho CWT indicator stocks in a geographic area.
   i. Problem: The southern inside sector of Southeast Alaska has only one small wild CWT indicator stock (Hugh Smith) with which to generate all stock parameters, including ER. The department bases management on wild-stock abundance and uses the wild-stock tagging in the region for management. The larger aggregation of wild stocks in the southern inside area is not likely well represented by the small CWT indicator.
   ii. Consequence: ERs, distribution, survival, etc. may not be indicative of all stocks in this area.
   iii. Solution: A program has been started on the Chickamin River, a stock that produces 50,000 to 100,000 adults annually, to estimate a full set of population parameters. This stock represents another life history and exploitation pattern present in this area. Future funding will need to be obtained to continue this program.
   iv. Cost: $150,000 annually.

**Sampling Issues**

8. Low sampling rate in selected fisheries.
   i. Problem: The traditional purse seine sampling rate is low overall (14-16%) and some individual net strata with significant catches are not sampled adequately.
   ii. Consequence: Precision of estimates for some stocks will be low and indicator stocks may be missed.
   iii. Solution: Raise sampling rates in total and assure temporal representation.
   iv. Cost: $30,000 annually.

## *Alaska Data Reporting, Coordination, and Validation*

9. Sample expansion for escapement CWTs from tagged wild stocks of Chinook and coho salmon from SEAK are unavailable on the RMIS database.
   i. Problem: The number of fish sampled in escapements and the escapement estimates are not reported to RMIS for SEAK wild stocks.
   ii. Consequence: Analysts cannot expand CWTs reported from escapements for SEAK wild stocks.
   iii. Solution: Contact Alaskan representatives on PSC technical committees to obtain the correct expansion factors for tag codes for each fishery.

10. Harvest reporting strata for commercial spring troll openings.
   i. Problem: The management strata for spring troll openings are much finer and more numerous (by sub-district statistical area-statistical week) than for the general summer and winter troll strata, which are managed and reported by area quadrant (multiple districts for each and by troll period—multiple statistical weeks). These openings are managed to maximize the harvest of Alaskan hatchery Chinook as they return in near-terminal areas, proximal to hatcheries.
   ii. Consequence: The fine-scale MUs cause inconsistent CWT sampling statistics for the spring troll fishery, such as a sub-district sampled at > 100% or 0%.
   iii. Solution: Redefine and map the reporting strata for spring troll fisheries to larger aggregates of time and area to be more consistent with the remainder of the accounting year for the SEAK troll fishery.
   iv. Cost: Minimal.

## *Canada Chinook and Coho Salmon*

**Tagging Issues**

1. Lack of CWT indicator stock coverage of production regions or stock aggregates.
   i. Problem: Major Chinook and coho production areas and life histories are poorly represented by CWT indicator stocks, which are used for assessments by the PSC technical committees. Chinook – A CWT indicator is needed for the central coast area, and 3-4 are needed to represent distinct life history patterns in the Fraser River not represented by the indicator for the Fraser River Lates. Coho – CWT indicators are needed to represent the central coast, northwest Vancouver Island and east Georgia Basin production regions and 3 of 4 production regions in the north coast.

ii. Consequence: Chinook - A number of large Chinook aggregates currently have no exploitation rate indicator to provide ERs and survival rates, or maturation rates as input data to the Coastwide Model. Coho – Due to lack of tagging, production in the unrepresented regions can not be modeled in the coho FRAM.
iii. Solution: Chinook - Indicator programs could be functional almost immediately for some of the aggregates if funding were secured for the escapement programs. Additional funding is needed to develop an adequate indicator for one (possibly two) Fraser River aggregates. Coho – Funding is required to develop tagging programs to represent the production regions.
iv. Cost: $1,235,000

2. Discontinuation of wild coho indicator programs.
   i. Problem: Due to lack of funding, several wild indicator programs were cancelled and in those remaining, escapement estimation and CWTs sampling are increasingly dependent on community volunteers.
   ii. Consequence: Wild coho indicators provide assessments of freshwater smolt production that cannot be assessed from hatchery stocks. Tag data in certain production regions has decreased overall or resulted in a greater proportion of the data coming from hatchery releases.
   iii. Solution: Greater funding would allow the optimization of existing indicator programs and allow the reinstatement of wild indicator programs.
   iv. Cost: Included in 1.

3. The coastwide standard tag release sizes for coho (40,000) and Chinook (200,000) are not met for some indicator stocks.
   i. Problem: When the coastwide standard tag release sizes are not met, usually too few CWTs are recovered to reliably represent stock dynamic and fishery impacts.
   ii. Consequence: In some cases, fishery and escapement recoveries are fewer than desired for producing reliable fishery harvest and brood statistics.
   iii. Solution: Where possible, steps are being taken to increase tag numbers for coho and Chinook. Tagging targets can be estimated by considering aspects such as survival and expected fishery and escapement sampling rates to produce desired precision for stock parameters.
   iv. Cost: $500,000

**Sampling Issues**

4. Voluntary Head Program for CWT recoveries from sport fisheries.
   i. Problem: DFO obtains CWT recoveries from all marine and freshwater sport fisheries through the voluntary submission of heads from adipose clipped fish into head depots.
   ii. Consequence: CWT recoveries may not represent the actual stock mixture; the magnitude of the bias is unknown. CWTs from unmarked fish in non-selective fisheries will not be obtained. Insufficient coho heads recovered in recent years,

while sufficient numbers of Chinook heads recovered: sport sector insufficiently informed about the value of coho CWT data.

iii. Solution: Studies are needed to determine the degree of bias in the distribution of observed CWTs. The results of the studies would be useful in determining the steps needed to improve CWT data from the sport fisheries. Improvements to voluntary recovery program, and/or direct sampling of sport fisheries to improve awareness and/or reduce bias.

iv. Cost: $150,000

5. Sport fishery catch estimates are incomplete but cover main periods of fishing activity.

   i. Problem: Catch is not estimated for all time periods and areas of the sport fishery. In addition, creel survey programs which obtain needed clip rate and CPUE data to estimate awareness do not cover all time periods (e.g., non-summer months in Georgia Strait) or areas (e.g., PFMAs 3-6 of northern sport; freshwater areas) where significant catch of indicators may occur.

   ii. Consequence: The estimated catch is incomplete and awareness factors to expand the CWTs turned in voluntarily by anglers must be derived from other times and areas for which awareness data are available.

   iii. Solution: The extent of catch estimation, sampling, and awareness needs to be reviewed across all Canadian sport fisheries. The tools used to estimate the total number of CWTs harvested will depend on funding. Options include additional creel surveys, improvements to study designs of current creel surveys, use of other survey instruments (e.g. mail surveys to recall a sample of licenses with recorded catch, charter and lodge logbooks, etc.), and status quo.

   iv. Cost: $750,000 to $1,500,000, depending on solution

6. Inadequate spatial and temporal representation of sport catch related to uncreeled areas, or lack of contribution of catch data and CWTs from all lodge and charter operations.

   i. Problem: DFO relies on cooperation from commercial lodge and charter operations to volunteer estimates of sport catch, and heads of adipose clipped fish; cooperation is less than universal. CPUEs and fishing effort may differ among lodge & charter fishers and the average fisher encountered by the creel survey.

   ii. Consequence: In some areas (e.g., WCVI, QCI, and Central Coast), lodge & charter operations represent a major portion of the sport harvest; catch estimates are incomplete because their catch is not accurately captured in the dockside creel surveys. In addition, the sample size of heads could be increased considerably with their contributions.

   iii. Solution: Improvements to the logbook program are needed to improve catch data, CWT recoveries and cooperation from more lodges.

   iv. Cost: $75,000

7. Inconsistent or lack of sampling and catch estimates for substantial Native fisheries.

   i. Problem: While improvements have been made to estimate Native fishery catches, most fisheries have either not been sampled or have been inconsistently sampled for CWTs where indicator stocks occur.
   ii. Consequence: Analyses such as cohort reconstructions are based on incomplete recovery data and the results are therefore, biased. Total exploitation and production are underestimated by an unknown and variable amount. Reduced quality of abundance forecasts, fishery impacts, and stock assessments.
   iii. Solution: When Native fisheries are open, they should be sampled to produce statistically valid and representative CWT recoveries. Agreements to sample and expand CWTs must be obtained and plans for random and representative sampling implemented.
   iv. Cost: $230,000

8. Lack of or incomplete sampling for unmarked CWTs in fisheries.
   i. Problem: Electronic sampling is not used in all fisheries, and in some cases unmarked and tagged fish are not processed.
   ii. Consequence: Unmarked recoveries are lacking or incomplete in the RMIS database and analyses of DIT releases will be compromised.
   iii. Solution: This has been an issue of funding level and allocation versus agency priorities. Utility of DIT recoveries in non-selective fisheries remains unclear. Reallocation of resources to sample unmarked CWTs could occur after canceling other programs.
   iv. Cost: $70,000 minimum

9. Lack of sampling in some fisheries where indicator CWTs are expected, which includes developing indicators.
   i. Problem: Reductions in funding have led to strategic cessation of sampling for CWTs in certain terminal areas where the presence of indicator CWTs is unlikely and in fisheries where species other than Chinook or coho are the target but where indicator CWTs may be landed in modest numbers. Fisheries with non-retention of Chinook and coho are not sampled (e.g. high volume net fisheries).
   ii. Consequence: This loss of CWTs, especially the indicator CWTs, is yet another unaccounted for bias in the results of cohort reconstructions. However, if assumption of minimal presence of indicator CWTs is true, then bias would be small.
   iii. Solution: Increased funding would enable the restoration of sampling in fisheries where CWTs are expected. Those fisheries where any indicator may occur would be given higher priority.
   iv. Cost: $50,000

10. Lack of coordination between the spatial and temporal coverage of regulations (e.g., MSFs) and the design of creel surveys.
   i. Problem: The design of the creel surveys has not been coordinated to match multiple and simultaneously occurring regulation sets (e.g., non-MSF, MSF and

mixed bag) which each need separate mark rate information and catch estimates for the estimation of CWTs reported caught under each regulation set.
ii. Consequence: Estimated numbers currently generated for individual recoveries from data collected across regulation boundaries are biased low or high depending on the regulation set.
iii. Solution: This problem has been recognized and steps have been taken to better coordinate the creel surveys with the regulations starting in 2006.
iv. Cost: $50,000

11. Escapements may have no or low CWT sampling rates or escapements may not be estimated quantitatively.
    i. Problem: Quantitative escapement estimates and CWT sampling are insufficient to use some stocks as indicators, or escapement sampling rates are too low to yield precise estimates of fishery impacts, stock dynamics, or total production at younger ages for effective sibling abundance forecasts.
    ii. Consequence: When escapements are not quantitatively estimated or sampled for CWTs, the stock cannot function as an indicator stock. When sampling rates are too low, the quality of parameters derived from CWTs (e.g. fishery impacts, stock dynamics) is reduced.
    iii. Solution: Estimate and sample escapements following a study design intended to produce the desired precision for indicator stock parameters.
    iv. Cost: $100,000

## *Canada Data Reporting, Coordination, and Validation*

12. Non-reporting of estimated numbers for some escapement CWT recoveries.
    i. Problem: While all recoveries are reported to the RMIS database, estimated numbers are only reported for those escapement recoveries associated with a population estimate known without error (i.e., generally the hatchery portion of the run).
    ii. Consequence: Estimated numbers are available for these recoveries and are used in technical committee analyses but they are unavailable to others via RMIS.
    iii. Solution: If requested by the PSC to report the estimated numbers, DFO would consider whether a change in its long standing policy of not reporting such numbers was warranted and any issues associated with reconciliation.
    iv. Cost: $80,000

13. Non-completion of important recovery fields in RMIS.
    i. Problem: DFO has not reported recovery records with the 'Adclip_selective' field completed.
    ii. Consequence: Analyses by technical committees or others examining impacts due to MSFs are hindered because it is unknown whether the recoveries occurred in a MSF or not. This affects analyses of Canadian and US stocks.

iii. Solution: Fishery regulations have become implemented on an increasingly fine spatial and temporal scale, often bisecting PFMA's. A mapping tool is needed to map the CWT recoveries to MSF, non-MSF, or other (e.g., mixed bag) regulations.

iv. Cost: $50,000

14. Completion of the 'Sampling Method' recovery field in RMIS.
    i. Problem: Most samples in commercial fisheries are sampled electronically and detected recoveries identified by an 'E'. However, the dissection of CWTs from unmarked heads has either been incomplete or none done at all. Yet analysts regard the E in the Sampling_Method field to indicate that unmarked CWTs were sampled, dissected, and reported for the fishery.
    ii. Consequence: Assumptions about the meaning of values in the Sampling_Method field leads to confusion in completion of this data field by agencies and in use by analysts. Analyses may be unknowingly based on incorrect or incomplete data and the results misinterpreted.
    iii. Solution: New values could be considered to indicate the above situation or a new field indicating whether there was complete dissection of unmarked heads could be added or analysts need to find other ways to determine whether the set of observed marked and unmarked recoveries in a fishery are complete (i.e., were sampled, dissected, and reported with equal probability). It could be helpful to have the PSC Data Sharing Committee review this issue and develop corrective options to assist analysts.
    iv. Cost: $50,000

15. Non-dissection of unmarked heads.
    i. Problem: CWTs in unmarked heads are detected via electronic sampling in commercial fisheries, the heads are taken but then those from ice boat samples are not dissected (though those from freezer trollers are).
    ii. Consequence: The sample of unmarked CWTs is incomplete and analysts must account for this. Because some unmarked CWTs are present in RMIS for the freezer troll component fishery, naïve analysts may assume that the marked and unmarked CWTs are equally complete, resulting in false interpretations from analyses.
    iii. Solution: Demonstration of the value of sampling for DITs in non-selective fisheries is needed.

16. Transparency of catch-sample data relationships in RMIS.
    i. Problem: Catch and samples are frequently aggregated across multiple time strata (basic unit = stat week) for the estimation of CWTs in commercial fisheries. These aggregated strata vary in duration among fisheries and years, i.e. catch and sample data may be summed across several stat weeks. Fields are available for coding in RMIS to allow for the recognition of non-standard time strata, but Canada has not populated them.
    ii. Consequence: Estimated numbers for individual recoveries are difficult to recreate given the catch and sample data reported in RMIS. Analysts will

encounter strata with sample data but apparently, no associated catch as well as strata with catch but apparently no associated sample. These cases are a 'coding' artifact due to samples and estimated catch falling into different stat weeks (the freezer troll catch is a special case of this issue).

iii. Solution: Canada populates the appropriate field in RMIS. Strata with sample numbers exceeding catch are generally infrequent, usually occur in terminal net fisheries, and generally represent small fisheries. Steps are being taken to populate the field in RMIS.

17. Reporting of catch-sample data to RMIS.
    i. Problem: Catch data in the catch-sample file of RMIS are incomplete because several Canadian recreational and Native fisheries, with no sampling, are not reported in the database.
    ii. Consequence: There can be substantial discrepancies between catch reported in RMIS and catch reported directly to PSC technical committees for reporting and analyses. Some analysts are unaware of the incompleteness of the catch-sample data and raise concerns when discrepancies are identified.
    iii. Solution: The PSC Data Sharing Committee could review the extent of this issue and clarify the intent of catch-sample file data and prepare options to reconcile the situation (if needed).

## *Washington Coast and Puget Sound Chinook and coho salmon*

### Sampling Issues

*Fishery Sampling Issues*

1. Puget Sound & Coastal Freshwater Recreational Sampling Programs (Chinook and Coho)
    i. Problem: Currently, WDFW does not have CWT sampling programs in place for many coastal and Puget Sound freshwater recreational fisheries in watersheds with significant numbers of tagged fish from groups used by CTC and CoTC
    ii. Consequence: If ERs associated with these fisheries are significant, lack of sampling will contribute to bias of ER estimates.
    iii. Solution: Implement sampling programs for sport fisheries occurring in watersheds where there are significant impacts on CWT groups, where feasible and cost-effective. Alternative approach, particularly applicable in situations of low catch rates is to devise methods for indirect estimation (e.g., apply nearby net fishery or hatchery sampling information to catch estimates).

2. Incomplete or inaccurate accounting of catches has been documented in Puget Sound fisheries. Contributing causes for incomplete accounting include cases where fishers sell harvest over the bank, sell the fish for eggs, or take fish home without reporting these fish on fish tickets. In addition to not being reported, this catch is not sampled for tagged fish.
    i. Problem: Unreported and unsampled catch of coho and Chinook salmon.

ii. Consequence: Estimates of total catch will be biased resulting in biased sample expansions for estimation of tagged fish in harvest. Where there is no sampling as well, the number of tagged fish will be underestimated.
iii. Solution: Implement independent estimates of commercial fish landings and sales to be compared with existing fish ticket system. Results of this study will identify magnitude and source of accounting problems. Once catch accounting problems are identified, sampling programs may be increased to meet objectives including coverage of fisheries with broad geographic span and to account for over-bank, egging, and non-commercial catches.

*Terminal area sampling general issues*

3. Chinook and coho escapement estimates
   i. Problem: Estimation methods for escapement are inconsistent and may be biased or imprecise. Chinook and coho escapement methods require review to reduce bias and/or increase precision.
   ii. Consequence: Biased or imprecise estimates of escapement result in biased estimates of tagged escapement and ERs, the degree of bias depends on the method used for accounting of CWT strays onto the spawning ground.
   iii. Solution: Review of escapement methods should be carried out within the next 3-5 years to evaluate where improvements are necessary.

4. Chinook and coho escapement CWT sampling
   i. Problem: Natural spawning areas are not adequately sampled.
   ii. Consequence: Biased or imprecise estimates of escapement result in biased and imprecise estimates of tagged escapement and ERs.
   iii. Solution: Review of spawning ground CWT sampling design, including identification of the distribution of straying CWTs (as opposed to distribution of natural origin spawners), should be conducted to define problem and evaluate where improvement is necessary.

*Terminal area sampling specific issues*

5. Nooksack Chinook escapement estimates.
   i. Problem: Nooksack escapement. Chinook escapement estimates are made using an expansion from index areas to total escapement. Index areas have changed in character and fish distribution, which may result in biased estimates of escapement in future. The expansion is based on estimates of total escapement from work done in 2000-2004.
   ii. Consequence: Biased or imprecise estimates of escapement result in biased estimates of tagged escapement.
   iii. Solution: Validate estimation of expansion using a mark-recapture study. Or develop a stratified random sampling approach without permanent index areas.

6. Nooksack sport fishery for fall Chinook.
   i. Problem: Sport fishery for fall Chinook since 2004 targeting hatchery fish (Samish fall indicator stock) is not consistently sampled.

ii. Consequence: Tagged fish not sampled and accounted for, resulting in bias in ERs.
iii. Solution: Sample sport fishery.

7. Samish fall Chinook terminal sport fishery estimation.
   i. Problem: Sport fishery is not sampled.
   ii. Consequence: Impacts to Samish fall double index tagged fish are not estimated which will result in bias estimate of total return of tagged fish
   iii. Solution: Sample sport fishery.

8. Skagit Chinook escapement estimation method includes ground and flight surveys for estimation of total number of redds. There are several stocks with indicator tag groups in the system, including springs in the Suiattle, Cascade and upper Sauk, summers in the upper Skagit and Sauk, and falls in the lower Skagit.
   i. Problem: Estimates for summer and fall stocks have inadequate numbers of flights and there is uncertainty as to redd life which is required for estimates using flight survey methods.
   ii. Consequence: Imprecise or biased estimates of tagged escapement.
   iii. Solution: Increase frequency of surveys currently done.

9. Skagit coho escapement estimation uses index areas expansion approach where expansion was estimated 16 years ago, and the index areas used represent <1% of total distribution of coho salmon.
   i. Problem: Estimation method used subject to substantial bias.
   ii. Consequence: Biased escapement estimates will result in biased estimates of total tagged cohort and ERs.
   iii. Solution: Coho escapement MR study to develop new escapement method; either random stratified or new index area expansion. Use study to evaluate distribution and recover tags for new sample design for Skagit coho.

10. Skagit coho escapement is not sampled for CWTs
   i. Problem: No sampling of coho escapement.
   ii. Consequence: Biased estimates of tagged escapement.
   iii. Solution: Require sampling from October through March. Index surveys cover only about 1-2% of total escapement.

11. Skagit sport fisheries include a coho fishery in Skagit and Lower Cascade which is not sampled.
   i. Problem: Coho fishery in Skagit and Lower Cascade not sampled.
   ii. Consequence: Coho tagged escapement underestimated.
   iii. Solution: Sample coho fishery for tags.

12. Skagit coho returning to hatchery escape above hatchery at a rate of 5-50% of the fish depending on the years and are not accounted for in estimate of hatchery origin escapement.

i. Problem: Design of hatchery rack results in an inconsistent rate of fish escaping above hatchery. Consequently, hatchery sampling is inconsistent and incomplete.
ii. Consequence: Biased estimate of hatchery escapement of tagged fish.
iii. Solution: Improve rack into hatchery. Until then count and sample above the hatchery.

13. Chinook escapement estimation in the Stillaquamish.
    i. Problem: Chinook escapement estimated as total redd counts assuming all areas are covered by foot, float, or flight. Viewing conditions for redd counts from foot surveys and flights are not always optimum, resulting in minimum estimates of escapement in some years.
    ii. Consequence: Biased estimates of escapement.
    iii. Solution: Improve escapement methods. Rely more on foot surveys and increase survey frequency. Redd life estimates need to be improved.

14. Stillaguamish coho escapement estimation.
    i. Problem: The method used is an index area expansion to total using expansion from 1970's. Method needs to be evaluated.
    ii. Consequences: Estimate is possibly biased.
    iii. Solution: Mark-recapture study is currently underway, for 3 years.

15. Snohomish Chinook escapement estimation. Total redd counts are made using ground surveys or flight surveys using redd life estimates and calculating total redds using area under the curve methods (AUC). Flight surveys are used for the Skykomish. Float surveys are used for the mainstem Snoqualmie; certain areas are missed in some years. Snohomish –The Pilchuk (Snohomish tributary) is surveyed by float methods and the upper Snohomish by flight.
    i. Problem: Estimates using AUC are subject to uncertainty that cannot be measured.
    ii. Consequence: Imprecise and biased estimates of total escapement lead to biased estimates of total CWT escapement.
    iii. Solution: Several options are possible for improvement of escapement estimation where flight surveys are currently used. 1. Flights could be increased and estimates of redd life could be improved. 2. Ground to flight expansion factors could be estimated. 3. Increase area coverage where ground surveys are used.

16. Snohomish Chinook escapement sample rates should be improved.
    i. Problem: Sampling rates for Chinook from the Snohomish are low.
    ii. Consequences: Imprecise estimates of number of tagged fish in escapement.
    iii. Solution: Increase sampling on Pilchuk and Lower Skykomish to improve sample size.

17. Wallace Hatchery has a large number of surplus Chinook carcasses that are not sampled (~10K).

i. Problem: Sample rate of total return is well under 100% in the hatchery
ii. Consequences: Skykomish indicator stock coming back to the Wallace hatchery are under sampled resulting in estimates of total return of tagged fish being imprecise.
iii. Solution: Increase sampling, and improve hatchery sample design.

18. Skykomish Chinook mark-selective fishery exploits a tagged stock that is a new PSC indicator stock.
    i. Problem: The sport fishery is not sampled for CWTs.
    ii. Consequence: Underestimate of tagged fish including indicator tag groups in the system.
    iii. Solution: Sample sport fishery

19. Snohomish coho escapement is subject to bias. There is a DIT in the Snohomish.
    i. Problem: Coho escapement is estimated using an index area to total expansion from 70's. Method needs to be evaluated.
    ii. Consequences: Estimate is possibly biased
    iii. Solution: Tulalip using BIA money to develop sample design for improving escapement method.

20. Snohomish coho sport fishery is not sampled. This represents a large coho fishery (7,300 coho in 2004).
    i. Problem: Wallace River hatchery has a DIT group and tagged fish harvested in sport fishery will not be estimated.
    ii. Consequence: Tag escapement underestimated for DIT group.
    iii. Solution: Sample sport fishery for tags.

21. Green River Chinook escapement sampling.
    i. Problem: Chinook escapement sampling. Currently not sampling below hatchery at Soos Creek. There is a DIT group returning to Big Soos Creek. There would also have to be an escapement estimate for Big Soos Creek. This estimate and sampling was done in the past but not currently. Some of the fish spawning in Big Soos may end up as carcasses in the mainstem. Also should review distribution of sampling in mainstem, relative to spawning distribution
    ii. Consequence: Underestimate tagged fish returning. Possible bias if mainstem sampling is not distributed in proportion to spawning.
    iii. Solution: Review distribution of hatchery fish that do not enter hatchery. Estimate escapement and sample in Big Soos Creek.

22. Big Soos Creek hatchery sampling.
    i. Problem: Fish escape upstream of the Big Soos Creek hatchery and are not sampled.
    ii. Consequence: Bias in estimate of tagged fish.
    iii. Solution: Replace weir for hatchery.

23. Green River Chinook escapement estimation.

i. Problem: Chinook escapement estimation needs review. Estimate using redd count surveys from flights and ground surveys. Use area/ground adjustments and expand from peak count to estimate total escapement. Currently using correction from years when had mark-recovery (MR) and redd count surveys. MR validations should be repeated systematically.
ii. Consequence: MR corrections can provide improvement in estimates, but could introduce bias if not validated on a consistent basis.
iii. Solution: Provide for MR study every 5 years for 2 years.

24. Green River coho escapement estimation.
i. Problem: Green river coho estimate of escapement. Escapement estimation for coho uses index areas with expansion to total. The expansion factor was estimated 25 years ago; the index used represents a small percentage of total distribution of coho salmon.
ii. Consequence: Biased escapement estimates will result in biased estimates of total tagged cohort and ERs.
iii. Solution: A coho escapement mark-recovery study is needed to develop a new escapement method; e.g., random stratified or new index area expansion. Use study to evaluate tag distribution and to help design a new sample method for Green River coho tag recovery.

25. Green river sport fishery for coho salmon.
i. Problem: Sport sampling inadequate; coho fishery in Green-Duwamish is not sampled.
ii. Consequence: Big Soos has a DIT stock that needs to be sampled, but returning tagged coho are underestimated.
iii. Solution: Sample coho fishery for tags.

26. Puyallup – White River. Indicator stock tagged at White River Hatchery
i. Problem: White River springs are trapped at the Buckley trap. Fish not taken into the White River Hatchery are counted and released above the dam. The method of counting is subject to bias (visual count by staff at dam). It is assumed that no tagged fish are released above dam, but this cannot be verified. There is no escapement estimate for fish in Lower White River below dam and no sampling of these fish.
ii. Consequence: Estimates of total escapement and tagged fish are probably biased.
iii. Solution: Improve sample design and methods used to count and sample White River fish at the dam. Survey and sample spring Chinook below the Buckley dam.

27. Skokomish Chinook escapement estimation.
i. Problem: Method used is redd count with marking of observed redds. In some areas redd counts may be biased low.
ii. Consequence: Estimate of escapement bias will result in biased estimates of ER.

iii. Solution: Validate estimation of escapement using mark recapture study.

28. Hood Canal coho escapement sampling.
    i. Problem: Escapement sampling in Hood Canal has increased, however there are no estimates of escapement for coho in most streams being sampled. The recovered tags cannot be expanded to total tagged fish in escapement.
    ii. Consequence: Estimates of total tagged return for George Adams hatchery and Big Beef Creek wild coho salmon are biased.
    iii. Solutions: Review escapement methods for Hood Canal streams and develop methods that allow estimation for streams surveyed.

29. Queets escapement estimation and sampling for coho and Chinook.
    i. Problem: Method used is a redd count, with index areas surveyed every year plus some supplemental areas. Carcasses are sampled for CWTs.
    ii. Consequence: Precision of estimates is currenly low.
    iii. Solutions: Increase frequency of surveys and the sample rate.

**Data Reporting, Coordination and Validation**

30. Reporting of escapement recovery and catch and sample data.
    i. Problem: Lack of standards for reporting spawning ground escapement estimates and sampling statistics.
    ii. Consequence: Error in reporting of estimated total and inaccurate estimates of tagged fish in escapement.
    iii. Solution: Standardized reporting statewide for purposes of CWT estimation and reporting.

## *Oregon Chinook and coho*

**Tagging issues - Chinook**

1. Geographically disperse CWT release groups within Willamette basin.
    i. Problem: Release groups for both DIT and SIT groups have been spread throughout the basin with no historic consistency. Different release strategies (locations etc) for a single tag code.
    ii. Consequence: Incomplete sampling within basin at various release locations. Needed sampling programs exceed the allocated resources required for adequate sampling.
    iii. Solution: Confine release group(s) within narrow geographic range. Confine both DIT and SIT releases to one hatchery or co-location.
    iv. Cost: Additional costs are estimated at $86,000 annually.

2. Only one Chinook ER stock to represent entire OR coast.
    i. Problem: Salmon River is currently the only functional Chinook ER stock to represent OR coast.
    ii. Consequence: Lack of proper representation of Oregon Coast natural production stocks with differing geographic distribution and maturation schedule. About one third of the production of the Oregon Coast consequently

has no representation via an associated release group. Earlier maturation life histories are observed in the Mid-Oregon Coast compared to the Northern Oregon Coast aggregate.

iii. Solution: Elevate Elk River to proper position as ER stock, development of Mid Oregon Coast (MOC) indicators to include Coquille and South Umpqua escapement indicator stocks as representatives of the MOC Chinook aggregate.

iv. Cost: Annual costs to tag, release, monitor, and sample a functional MOC aggregate are estimated at $374,000 2007 US dollars.

**Tagging Issues- Coho**

3. Lack of CWT groups to represent all coho production regions.
   i. Problem: There is a paucity of CWT coho release groups in Oregon.
   ii. Consequence: Lack of representation of major production groups.
   iii. Solution: Coho production facilities on the Oregon coast have been re-vamped in the recent past with agency prioritization on natural production groups over supplementation programs. Currently there are two coho DIT groups released in Oregon, one in the Sandy River and the other from the Rogue. Coho SIT releases originate from the Rogue, Nehalem, Rock Creek (Cow Creek stock from Umpqua), most all coho release groups in the Columbia have an index group. There is opportunity to begin wild-stock coho tagging in Columbia tributaries, although the majority of outmigrant coho smolts are currently being trapped on the Washington side of the river.

**Sampling Issues**

4. Inconsistent use of electronic sampling in ocean fisheries sampling of Buoy 10 in the Columbia River.
   i. Problem: Ocean fisheries sampling electronically sampled for Spring Chinook and coho but not for Fall Chinook (use time of year to differentiate).
   ii. Consequence: Recoveries from unmarked CWT fish not sampled.
   iii. Solution: ODFW recognizes the need to modify sampling programs in the Columbia River.

5. Escapement monitoring in Willamette poorly coordinated.
   i. Problem: No centralized overview of CWT sampling programs within the basin; unmarked fish not examined for tags at escapement.
   ii. Consequence: Confounding of data, lack of consistency in reporting of data. Cannot use Willamette DIT recoveries to evaluate impact of MSF in Willamette on unmarked fish.
   iii. Solution: Provide overview of basin's sampling. Statewide workgroups to provide overview of regional CWT sampling and reporting responsibilities have been initiated and both Columbia River and Marine Regional groups have already convened. Other regional workgroups dealing with specific monitoring and reporting needs are planned and will help to provide understanding to regional authorities. Additional escapement and terminal fisheries monitoring would require the re-allocation of scarce resources within regional districts. Cost estimations as to what needed sampling programs (a full-basin creel

sampling program and additional spawning ground sampling) have been initiated, but genuine estimates are not available at this time. ODFW has committed to providing needed facilitation and direction both within the Willamette basin and statewide.

**Data Reporting, Coordination, and Validation**

6. Data reporting for Willamette ER stock.
   i. Problem: Estimates for data expansion for Willamette sport catch and escapement are not provided to the RMIS database. Expansion and analysis takes place externally to RMIS.
   ii. Consequence: Data residing on RMIS are not representative of agency estimates of catch and escapement.
   iii. Solution: Report expanded Willamette sport and escapement data to RMIS. As part of a larger state-wide data reporting system overhaul in the summer of 2007, this issue is slated to be addressed.
   iv. Cost: This is estimated to cost about $10,000.

7. CWT release reporting.
   i. Problem: Updated information available through preliminary (August) and annual reports (March) to PSMFC. Only available records are entered. Data quality checks and training opportunities are limited. Many groups remain unreported from regional biologists for several months.
   ii. Consequence: Timeliness of data reporting compromised.
   iii. Solution: Timelines for reporting of data and deadlines shared within agency.

8. CWT recovery data.
   i. Problem: Sampling programs separate data from physical snout samples. Tags are decoded and re-associated with recovery data by third party, i.e., CWT data base coordinator. This practice leads to "missing" data, because (1) neither party is aware of what constitutes a "complete" data set and (2) high likelihood of substantial time lag (months, sometime years) between data collection and reporting compounds difficulty to retrieve missing data from field staff.
   ii. Consequence: Data are lost; tags cannot be tied to sample information (e.g., strata information) and are rejected by RMIS.
   iii. Solution: Tie physical snout samples to biological data collected at time of sampling. A statewide "snout tag" distributor has been established who is responsible for centralized disbursement and tracked collection of both snouts and data tags. ODFW is confident that with the advent of the centralization of this responsibility, the problem can be overcome.

9. DIT reporting problems.
   i. Problems: There are problems with the way DIT groups have been reported to RMIS from ODFW.
   ii. Consequence: The DIT data is confounded.
   iii. Solution: Being worked on.

## *Columbia River Chinook*

**Tagging Issues**

1. Hanford wild tagging.
   i. Problem: In some years, environmental conditions limit ability to collect enough fish to tag to reach 200,000 standard.
   ii. Consequence: Number of recoveries generated is less than needed and precision suffers.
   iii. Solution: Additional resources for tagging effort.

2. Hatchery groups representing wild groups.
   i. Problem: Hatchery tag groups may not adequately represent wild groups of interest.
   ii. Consequence: Estimates of impacts on wild groups may be biased.
   iii. Solution: Establish wild stock tagging program where feasible.

3. Lack of representative tagging.
   i. Problem: Chinook tagging downstream of Bonneville Dam discontinued beginning 2006 due to budget reductions.
   ii. Consequence: Stocks are not adequately represented.
   iii. Solution: Reinstitute tagging program.
   iv. Cost: An additional $116,000 annually.

4. Lower Columbia DIT groups.
   i. Problem: Mass marked hatchery groups representing wild production.
   ii. Consequence: CWT groups no longer representative of wild production.
   iii. Solution: Expand the size and number of DIT groups. Tagging levels should be increased where tag recoveries goals are not met. Lower Columbia tule production groups have been DIT tagged with 200K marked and tagged group and 200K tagged group for the first time in 2007.
   iv. Cost: This has come at a cost of $90,000 for this release group.

**Sampling Issues**

5. Direct sales to public.
   i. Problem: Fish sold directly to the public by treaty fishermen are not sampled.
   ii. Consequence: Incomplete sampling, non-representative sampling, lost information, and potential bias in estimates.
   iii. Solution: Equip samplers with appropriate gear to collect tags.

6. Mainstem Recreational Fisheries.
   i. Problem: Up to 25% of strata representing 37-60% of the catch is sampled at a rate <20%.
   ii. Consequence: Incomplete sampling.
   iii. Solution: Additional resources.

7. Tributary Fisheries.

i. Problem: Low sampling or no sampling due to resources prioritized to the larger fisheries.
ii. Consequence: Incomplete sampling.
iii. Solution: Additional resources.

8. Mark-Selective Fisheries.
   i. Problem: Difficult to estimate numbers of released fish and release mortality. Differential mortality of marked and unmarked groups.
   ii. Consequence: Sampling not representative of impacts on unmarked groups. Bias in total mortality estimate.
   iii. Solution: Consider functional DIT group. Additional sampling coverage in fisheries and escapement. An additional DIT group of tule-origin Chinook will be released from Big Creek beginning spring of 2007. Sampling programs to allow for sufficient DIT representation will need to be in place to allow for unbiased assumptions to be made from the subsequent DIT analysis.
   iv. Cost: This costs an additional $90,000 annually for marking activities.

9. Hatchery sampling.
   i. Problem: Samplers not available at all times because of higher sampling priorities.
   ii. Consequence: Increased uncertainty in hatchery production estimates.
   iii. Solution: Requires that subsampling is accounted for in expansion of tagged recoveries. Additional resources are needed.

10. Escapement sampling.
   i. Problem: Inadequate or no sampling. There is potential size selectivity in carcass sampling.
   ii. Consequence: Increased uncertainty in natural production estimates
   iii. Solution: Additional resources needed. Sampling programs need to be designed to representatively cover spawning areas.

11. Columbia River Commercial harvest expansions.
   i. Problem: Commercial landings are expanded from poundage records tied to biological sampling. A true fish count does not occur.
   ii. Consequence: Increased uncertainty in estimates may be introduced, and subsequent variance around the point estimate will be dependent upon the sampling rate.
   iii. Solution: Report numbers of fish as well as poundage. ODFW believes this to be logistically difficult and fiscally prohibitive. This could be a more accurate method than trying to get a fish by fish count. There is a powerful incentive for both the buyer and fisher to provide as precise of a poundage estimate as possible. The variance associated with the catch estimate is more dependent on biological information (weight per fish) than other drivers.

12. Visual sampling in mainstem Columbia net and sport fisheries. (same as above)

i. Problem: Mark-selective Columbia net and sport fisheries (spring Chinook, summer Chinook, coho) are sampled electronically, but the fisheries for fall Chinook are not electronically sampled because they are non-selective.
ii. Consequence: Adequate sampling for recoveries of fall Chinook more difficult as proportion of clipped untagged fish increases.
iii. Solution: Consider electronic sampling for fall Chinook. Electronic sampling for fall Chinook is likely in the near future below Bonneville.

13. Columbia River creel sampling issues.
    i. Problem: Sampling program has not kept up with the development of summer recreational fisheries on Columbia River. Sampling is non-representative as some strata are sampled and other strata are not sampled. Catch sample rates may be lower in developing fisheries.
    ii. Consequence: Bias of estimates of sport fisheries catch.
    iii. Solution: Increase sampling given appropriate funding.

**Data Reporting, Coordination and Validation**

14. Inter-agency tag recovery and reporting.
    i. Problem: Multiple agencies sampling same fishery or escapement area.
    ii. Consequence: Potential confusion, incomplete data.
    iii. Solution: Inter-agency agreement/plan on sampling.

## *Columbia River Coho*

**Tagging Issues**

15. Hatchery groups representing wild groups.
    i. Problem: Hatchery tag groups may not adequately represent wild groups of interest, especially in mark-selective fisheries.
    ii. Consequence: Estimates of impacts on wild groups may be biased.
    iii. Solution: Establish wild stock tagging program where feasible. A preliminary wild-group tagging effort could be engaged in either the Clackamas and or Sandy production basins. A collaborative effort between state, federal and industry groups could feasibly tag about 20K outmigrant coho, but costs would likely be prohibitively high to allow for mobile tagging crews to follow each of the screw-trap operators in these basins. An estimated 50k smolts would be available for tagging between Cedar Creek and Cowlitz basins on the Washington side of the Columbia. Additional groups of juveniles would be available through collaboration with Washington. Groups of interest on the lower Columbia would be much more logistically challenging to provide wild-stock tagging

**Sampling Issues**

16. Mainstem Recreational Fisheries.
    i. Problem: Up to 28% of strata representing 59-85% of the catch is sampled at a rate <20%.
    ii. Consequence: Incomplete sampling, bias estimates.
    iii. Solution: Additional resources need to increase sampling.

17. Tributary Fisheries.
    i. Problem: Low sampling or no sampling in tributaries since resources are prioritized to larger fisheries. Catch in most tributary areas is small but stock specific.
    ii. Consequence: Incomplete sampling, bias estimates.
    iii. Solution: Additional resources needed to increase sampling.

18. Mark-Selective Fisheries.
    i. Problem: Difficult to estimate number of released fish and the release mortality. Differential mortality of marked and unmarked groups.
    ii. Consequence: Sampling is not representative of impacts on unmarked groups. Bias in total mortality estimate.
    iii. Solution: Consider functional DIT group.

19. Hatchery sampling.
    i. Problem: Samplers not available at all times.
    ii. Consequence: Bias in escapement estimates.
    iii. Solution: Additional resources needed to provide more samples.

**Data Reporting, Coordination and Validation**

20. Inter-agency tag recovery and reporting.
    i. Problem: Multiple agencies sampling same fishery or escapement area.
    ii. Consequence: Potential incomplete data if there is no interagency coordination.
    iii. Solution: Inter-agency agreement/plan on sampling.

## *California Chinook*

**Tagging Issues - Chinook**

1. Variable marking of fall run hatchery production.
    i. Problem: Fall run production is not consistently or representatively tagged.
    ii. Consequence: Unable to determine hatchery and natural contribution to the ocean fisheries and escapements.
    iii. Solution: Mark a constant fraction (25%) of the California (IGH & Central Valley hatcheries) fall run production.

2. Many streams have no CWT groups representing their production.
    i. Problem: Yuba River and other Central Valley and coastal tributaries currently have no CWT release groups representing them in the fisheries.
    ii. Consequence: Lack of proper representation of California stocks with differing geographic distribution and maturation schedule.
    iii. Solution: Develop marking and release strategies in hatcheries that would mimic the life history of the wild Chinook stocks.

3. Natural stocks in many tributaries have no CWT groups representing their production.

i. Problem: Wild tagging requires the use of half tags and half tags are difficult to detect with current electronic sampling.
ii. Consequence: Tags are missed and estimates of CWT returns are underestimated.
iii. Solution: Develop hatchery surrogates to represent wild Chinook stock population parameters. Develop GSI methodologies in coastwide fishery sampling to fill the gap created by electronic sampling. Use new small tags that are easier to read but more expensive.

**Sampling Issues - Chinook**

4. Non-representative sampling of the ocean commercial harvest.
   i. Problem: Management needs finer stock composition detail by catch area.
   ii. Consequence: Inferences of the catch and effort can be made only for large areas.
   iii. Solution: Improve reporting of ocean catch area block number.

5. Non-representative sampling of the ocean commercial harvest.
   i. Problem: Fish landed by freezer boats are not separated into catch from specific management areas.
   ii. Consequence: Inferences of catch and effort from these boats are difficult to make.
   iii. Solution: Seek regulations to enforce separation of catch by management area, or provide on-board samplers, or implement a Vessel Monitoring System with onboard GSI/CWT sampling.

6. Incomplete or no sampling of Central Valley (CV) and coastal inland recreational fisheries.
   i. Problem: The Central Valley river recreational Chinook fishery harvests a large number of the annual CV terminal run that is not consistently sampled for CWT recoveries or catch and effort.
   ii. Consequence: Assumptions have to be used about this fishery which can be erroneous from year to year.
   iii. Solution: Develop and implement a fishery sampling plan to estimate total catch, effort, and CWT contribution to the Central Valley recreational Chinook salmon fishery.

7. Insufficient or no sampling of Central Valley (CV) and coastal escapement.
   i. Problem: Some Central Valley tributaries and most all CA coastal streams have incomplete or no escapement surveys.
   ii. Consequence: Inconsistent or no escapement estimates and CWT monitoring.
   iii. Solution: Develop and implement a CV and CA coastal escapement sampling plan to estimate total escapement and CWT contribution to these streams.

8. Constant fractional marking of Central Valley fall-run salmon will increase the number of heads being recovered in fisheries and inland monitoring programs.

i. Problem: Increased adipose fin clip rate in the fishery increases the number of heads collected by the Department. Commercial buyers are increasingly reluctant to allow sampling due to weight of fish heads removed and an increasing fraction of the heads have no tags resulting in no data for the cost and effort of sampling.
ii. Consequence: Less cooperation by the commercial buyers and increasing difficulty in maintaining proper sampling rates of commercial landings.
iii. Solution: Improve enforcement of sampling and CWT collection laws.

9. Constant fractional marking of Central Valley fall-run salmon will increase the number of heads being recovered in fisheries and inland monitoring programs.
   i. Problem: Increased adipose fin clip rate in the fishery increases the number of heads collected by the Department.
   ii. Consequence: Additional staff will be required to collect and process the additional workload.
   iii. Solution: Additional funding and staffing will be required. Seek funding through the Department BCP process and CALFED funds to supply additional staff and equipment needed.

**Issues with Estimation of Total Harvest or Escapement**

10. Uncertainty in estimates of sport catch associated with private access areas.
    i. Problem: Fish landed by private access boats are not sampled.
    ii. Consequence: Uncertainty of inferences of catch and effort from these boats are difficult to estimate.
    iii. Solution: Implement a pilot sampling program to determine the degree of uncertainty if any associated with making inferences about their catch and effort.

11. Unknown bias associated with spawning escapement survey methodologies.
    i. Problem: Carcass surveys for estimation of total Chinook escapement have unknown size, stock, and sex bias.
    ii. Consequence: Natural spawning escapement estimates do not represent the real escapement numbers.
    iii. Solution: Implement counting weirs to measure bias in specific Chinook salmon surveys (Upper Sacramento River, Feather River).

12. Unknown bias in estimates of age structure.
    i. Problem: Age structure of the Central Valley stocks is currently determined by length frequency and designates only two general size classes: grilse and adults.
    ii. Consequence: Inaccurate age class estimates cause the accuracy of the Central Valley Index to be highly variable and unreliable.
    iii. Solution: Implement and fund age determination program for Central Valley escapement.

13. Lack of organized oversight to Central Valley salmon escapement monitoring.

i. Problem: No organized oversight of Central Valley escapement monitoring.
ii. Consequence: Inefficient use of resources and a shotgun approach to addressing monitoring needs
iii. Solution: Develop agency oversight on funding priorities to improve the consistency of escapement monitoring.

**Data Reporting, Coordination and Validation**

14. Estimation methodologies.
    i. Problem: Lack of technical oversight and review of sampling methods and estimation methodologies.
    ii. Consequence: Unknown bias of escapement estimates.
    iii. Solution: Implement a program to review sampling and estimation methodologies.

15. Data reporting.
    i. Problem: Inconsistent reporting on state wide CWT releases and recoveries.
    ii. Consequence: Not all of the California data is available on the RMIS system.
    iii. Solution: Provide agency oversight and positions that would be responsible for submitting all California CWT and catch/effort data to PSMFC.

16. Data reporting.
    i. Problem: Management needs finer detailed catch area stock composition and effort data for ocean fisheries.
    i. Consequence: Limited inferences on stock composition.
    ii. Solution: Develop methods for verifying area-of-catch for CWT recoveries to allow for finer resolution of reporting than is currently possible.

## *California Coho*

**Sampling Issues - Coho**

17. Incomplete or no sampling of coastal recreational fisheries.
    i. Problem: The coastal recreational salmon fisheries catch and release (no directed take allowed of ESA listed stocks) an unknown number of the annual coho escapement that is not consistently sampled for CWT recoveries or catch and effort.
    ii. Consequence: Assumptions have to be used about this fishery which can be erroneous from year to year.
    iii. Solution: Develop and implement a fishery sampling plan to estimate total catch, effort, and CWT contribution to the inland coastal recreational salmon fishery.

18. Incomplete or no sampling of coastal coho salmon escapement.
    i. Problem: Inadequate or no sampling of California coastal streams.
    ii. Consequence: Increased uncertainty in natural production estimates.
    iii. Solution: Additional resources are needed to improve sampling. Sampling program needs to be designed to representatively cover spawning areas.

# Appendix B. Specifications for a Prototype Tool Evaluating Alternative Sampling and Marking Strategies for Coded-Wire-Tag (CWT) Studies[4]

At the May CWT workgroup session, discussion centered on the development of a CWT planning tool that would help evaluate the implications and consequences of implementing various actions taken by jurisdictions coastwide to improve the CWT program. A small subgroup (Marianna, Gary, Annette, Norma) convened to further discuss desired attributes of a tool specifically designed to provide information to help plan and evaluate alternative measures to improve the quality of data that can be derived from CWT experiments. This draft reflects Gary's attempt to summarize the results of the subgroup deliberations; an auxiliary Excel workbook, *CWTToolTemplate.xls,* contains examples of various formats that could be employed in the tool.

**Purpose:**

Provide a Tool to facilitate exploration and evaluation of the coast-wide effects of alternative sampling and marking strategies on selected statistics derived from cohort analyses of CWT experiments.

**Language & Platform:**

MS Visual Basic (Net). PC Windows OS

**Structure:**

<u>Species:</u> Chinook and coho salmon

<u>General Description.</u> The Tool will integrate the following components:

(a) FRAM-type, multi-stock, multi-fishery simulations to generate CWT recoveries of indicator stocks which would be expected to result from changes in fishing patterns, sampling rates, and marking levels;
(b) databases of indicator stocks containing the data utilized by the PSC Chinook (CTC) and Coho (CoTC) technical committees to perform cohort analyses for selected indicator stocks;
(c) a set of user-defined *packages* of alternative CWT sampling programs for individual fisheries and marking levels for individual indicator stocks;
(d) a module that adjusts historical observations of CWT recoveries of indicator stocks to reflect expected impacts of implementing specific sampling and marking packages;

[4] Gary S. Morishima, July 2006

(e) a module that performs cohort analyses on the indicator stocks and computes selected statistics that describe the effects of the packages on statistical uncertainty of CWT-based statistics;
(f) a *goal seeking* module designed to provide answers to a limited set of specific tagging and sampling questions; and
(g) user interfaces to define/select options and examine expected results.

The functions of the Tool would be accessed via a system of menus. The main menu would depict the following options:

| | | | | |
|---|---|---|---|---|
| Define Scenarios | Select Scenarios | RUN | Results | ASK |

## Define Scenarios

The Define Scenarios button enables the user to define packages of alternative fisheries, sampling regimes, and tagging levels. Clicking on the Define Scenarios would depict the following options

| | | | |
|---|---|---|---|
| Fisheries | Sampling | Tagging | Risk |

Selecting the *Fisheries* button would display the familiar FRAM input form used to provide specifications for individual fishery strata (quota, harvest rate scalar, mark selective, etc.)

Selecting the *Sampling* button would display an input screen to define a sampling scenario. After definition, the scenario would be saved in a database. - see worksheet *FishSampling* in *CWTToolTemplate.xls*.

Selecting the *Tagging* button would display an input screen to define alternative tagging levels for a given stocks - see worksheet *TaggingLevels* in *CWTToolTemplate.xls*. After definition, the scenario would be saved in a database.

Selecting the *Risk* button would display an input screen to describe acceptable levels of uncertainty surrounding a statistic of interest for the purpose of establishing a target ER. For example, the user could specify that the management objective would be to ensure that there is no greater than a y% chance that the ER on a given stock would not exceed X%. See worksheet *RiskDefn* in *CWTToolTemplate.xls*. After definition, the scenario would be saved in a database.

## Select Scenarios

The Define Scenarios button enables the user to define packages of alternative fisheries, sampling regimes, and tagging levels. Clicking on the Define Scenarios would depict the following options:

Sampling Tagging Risk

Selecting the *Sampling* button would display a system of pull down menus for individual fisheries to allow the user to select from defined sampling scenarios for each FRAM fishery. A single click on a particular scenario would display a summary description. A double click would select the sampling scenario. See worksheet *Sampling* in *CWTToolTemplate.xls*.

Selecting the *Tagging* button would display a system of pull down menus to allow the user to select from defined tagging scenarios for each FRAM stock. A single click on a particular scenario would display a summary description. A double click would select the tagging scenario. See worksheet *Tagging* in *CWTToolTemplate.xls*.

Selecting the *Risk* button would display a system of pull down menus to allow the user to select from defined risk scenarios to evaluate. A single click on a particular scenario would display a summary description. A double click would select the risk scenario. See worksheet *Risk* in *CWTToolTemplate.xls*.

Run

The *Run* button initiates a simulation run. A sequence of events would be triggered: (1) the user-selected packages for evaluation and the fishery specifications would be saved in a *.cmd*-type file familiar to FRAM users; (2) fisheries would be simulated; (3) sampling and tagging packages would be employed to estimate CWT recoveries by stock and fishery strata; (4) cohort analysis would be performed and uncertainty statistics would be computed; and (5) results would be saved for generation of output reports. A general schematic is presented in fig 1 below.

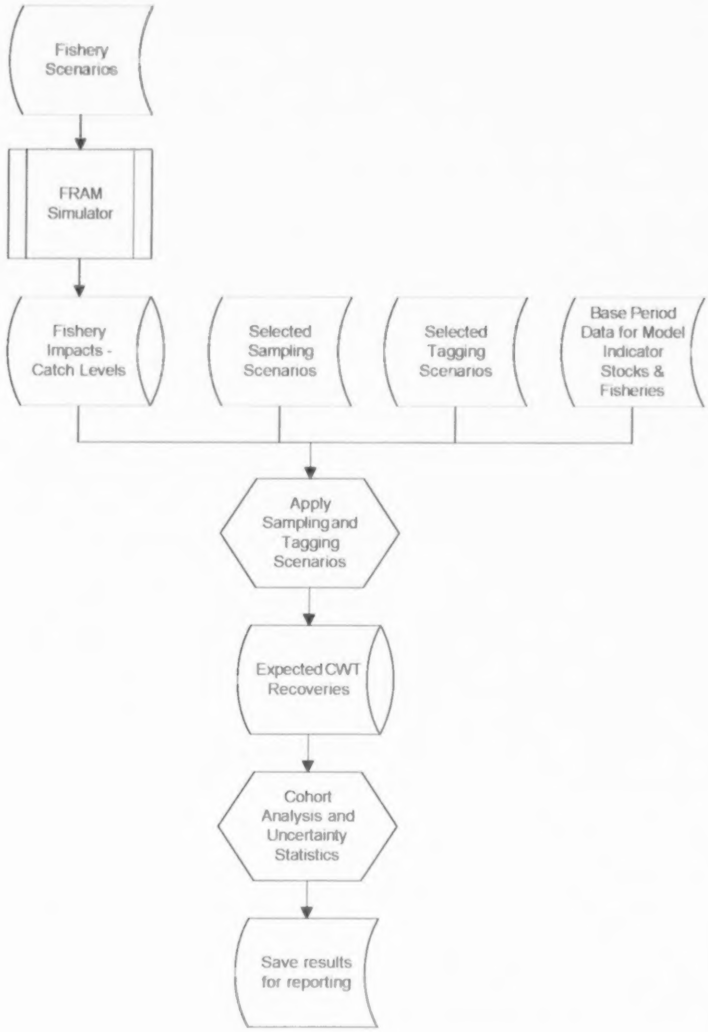


Fig 1. Schematic for Run Button

Estimated CWT recoveries

The expected CWT recoveries are computed by step 3 (the top hexagon) by taking into account changes in stock composition, sampling rates and marking levels from the FRAM base period. Expected CWT recoveries are simply the estimated CWT recoveries during the Base Period multiplied by four scalars as indicated below:

$$ECWT_{s,a,f,t} = BPCWT_{s,a,f,t} * \frac{Catch_{f,t}}{BPCatch_{f,t}} * \frac{StkComp_{s,a,f}}{BPStkComp_{s,a,f}} * \frac{SampRate_{f,t}}{BPSampRate_{f,t}} * \frac{Tags_s}{BPTags_s}$$

where:

| | |
|---|---|
| $ECWT_{s,a,f,t}$ | Estimated CWT Recoveries for stock s, age a, in fishery f, time period t |
| $BPCWT_{s,a,f,t}$ | Estimated CWT Recoveries for stock s, age a, in fishery f, time period t during the model base period |
| $Catch_{f,t}$ | Projected total catch in fishery f, time period t |
| $BPCatch_{f,t}$ | Estimated total Base Period catch in fishery f, time period t |
| $StkComp_{s,a,f}$ | Projected proportion of catch in fishery f, time period t, comprised of stock s, age a fish |
| $BPStkComp_{s,a,f}$ | Estimated proportion of base period catch in fishery f, time period t, comprised of stock s, age a fish |
| $SampRate_{f,t}$ | Specified catch sampling rate in fishery f, time period t |
| $BPSampRate_{f,t}$ | Base period catch sampling rate in fishery f, time period t |
| $Tags_s$ | Specified tagging level for stock s |
| $BPTags_s$ | Base period tagging level for stock s |

The first scalar is the ratio between the simulated catch under the proposed regulations and the catch during the model base period. For example, if the simulated catch is half the base period level, then the expected CWT recoveries would simply equal half the estimated CWT recoveries during the Base Period, all else being equal.

The second scalar is the ratio between the simulated catch composition under the proposed regulations and the catch composition during the model base period. This scalar is included because the stock composition would be expected to change from the Base Period as the simulation progresses through time.

The third scalar is simply the ratio between the catch sampling rate specified in the selected sampling package scenario and the catch sampling rate reported during the model base period.

The fourth scalar is simply the ratio between the tagging level specified in the selected tagging scenario and the tagging level reported during the model base period.

Cohort Analysis

Because FRAM is designed to operate for a single season, different procedures would need to be employed for Chinook and coho.

Coho: Fishery exploitation of coho salmon occurs predominantly during the last few months of ocean residence. Consequently, a normal cohort analysis can be performed using data generated by FRAM.

Chinook. Because fisheries in a single year exploit multiple broods of mature and immature Chinook, estimates of fishery impacts generated by FRAM will not form a suitable basis for routine cohort analysis based on reconstruction methods. Two alternative forms of pseudo

cohort analyses could be applied, however. In one alternative, age-specific cohort sizes would be computed based on base period maturation rates, estimated mortalities and escapements.

$$Cohort_{s,a} = \frac{TermFishingMortalities_{s,a} + \dfrac{Escapement_{s,a}}{PreSpawnSurvRate_{s,a}}}{MatRate_{s,a}} + PreTermFishingMortalities_{s,a}$$

where:

| | |
|---|---|
| $Cohort_{s,a}$ | Estimated Pre-Fishery cohort size for stock s, age a |
| $TermFishingMortalities_{s,a}$ | Estimated catch and incidental fishing mortalities in terminal fisheries stock s, age a |
| $Escapement_{s,a}$ | Estimated spawning escapement for stock s, age a |
| $PreSpawnSurvRate_{s,a}$ | Assumed post-fishery, pre-spawning survival rate for stock s, age a |
| $MatRate_{s,a}$ | Base period maturation rate for stock s, age a |
| $PreTermFishingMortalities_{s,a}$ | Estimated catch and incidental fishing mortalities for stock s, age a |

Alternatively, mortalities in preterminal fisheries could be expressed in adult equivalents and an initial adult equivalent cohort size could be computed for use in cohort analysis.

$$\text{AEQCohort} = \sum_a \frac{\text{TermFishingMortalities}_{s,a} + \dfrac{\text{Escapement}_{s,a}}{\text{PreSpawnSurvRate}_{s,a}}}{\text{MatRate}_{s,a}} + \sum_a \text{PreTermFishingMortalities}_{s,a} * \text{AEQ}_{s,a}$$

where: $AEQ_{s,a}$ = Adult Equivalence Factor for preterminal fisheries for stock s, age a.

ERs – Statistics of Interest

The effects of alternative sampling programs and tagging levels on the uncertainty surrounding CWT-based statistics can be evaluated through the concepts of bias and precision surrounding estimates of ERs. Bias is commonly expressed as the squared difference between the CWT-based estimate of ERs and the true ER. Precision is commonly expressed in terms of variance.

Uncertainty has been defined by SFEC as the squared difference expected values of the reflected by the MSE statistic (SFEC 2002):

$$\sum_f (TrueER_{s,a,f} - EstER_{s,a,f})^2 + Variance(EstER_{s,a,f})$$

While it is not possible to estimate the true ERs and variances surrounding those estimates without knowing the true values of both the ER and the stock composition of the populations exploited by various fisheries, true catches, and true sampling rates, Bernard and Clark provide a means of approximating those variances (Bernard et al. 1998).

Two cohort analyses would be performed for each stock using different data sets. One data set would consist of FRAM estimates of CWT recoveries under the selected sampling and marking scenarios. The second data set would consist of FRAM estimates of catches and incidental fishing mortalities of a model stock divided by the Production Expansion Factors (PEFs) associated with the CWT group, adjusted for marking levels.

$$AdjFRAMmorts_{s,a,f,t} = \frac{FRAMmorts_{s,a,f,t}}{PEF_s * \dfrac{Tags_s}{BPTags_s}}$$

where:

| | |
|---|---|
| $AdjFRAMmorts_{s,a,f,t}$ | FRAM estimates of mortalities for stock s, age a, in fishery f, time period t, adjusted so magnitude is comparable to CWT release size under selected tagging scenario |
| $FRAMmorts_{s,a,f,t}$ | FRAM estimates of mortalities for stock s, age a, in fishery f, time period t represented by the CWT release group |
| $PEF_s$ | Production Expansion Factor for CWTs from stock s during the model base period |
| $Tags_s$ | Specified tagging level for stock s |
| $BPTags_s$ | Base period tagging level for stock s |

ERs computed using the second dataset would represent "true" values for comparison with estimates generated from cohort analysis using the CWT recovery data set. Using Bernard and Clark's formulas, estimates of ERs and associated variances can be computed for these two datasets.

Results

Selecting the *Results* button would allow the user to select from a set of pre-formatted reports or to generate custom reports, similar to the capacity already incorporated into FRAM.

Ask

Selecting the *Ask* button from the main menu would enable the user to use the tool to ask for advice concerning certain common aspects of CWT experimental design:

(1) How many CWTs should be applied?

(2) What sampling rate should be used?

(3) Where should sampling funds be allocated to get the best estimate of the statistic of interest?

Constructing the Tool:

Steps to take:

(a) Put together the set of statistical methods (algorithms) to quantify the effect of marking levels and sampling programs on uncertainty, expressed in terms of accuracy and precision. These algorithms should focus on a limited set of questions such as: (1) age-specific ERs; (3) total fishery ERs on a brood.

(b) Identify data requirements for the algorithms:

- Marking/Tagging history by production region
- Historical profiles of fishery-related mortalities for major stock groups
- Historical CWT-based estimates of survival rates to catch + escapement
- Expected juvenile mortality pre-ocean entry (e.g., historical estimates of downstream juvenile passage mortalities by stock and dam)
- Post-fishery, pre-spawning mortality rates (e.g, historical estimates of upstream adult passage mortalities by stock and dam)
- Marking (CWT, clipping, both) costs per thousand fish
- Sampling requirements and costs by fishery
- Sampling costs for escapements (likely, stock-specific)
- Parameters for estimation of non-catch mortality (e.g., release mortality, drop-off, unmarked-retention error, mark recognition error)

(c) Collaborate with agency decision-makers to identify metrics that would best inform their decisions.

(d) Design the Tool, develop detailed specifications, & collate the data required for parameterization/evaluation.

(e) Construct, validate, and test the Tool.

# Appendix C. Equations used in construction of a simple decision-theoretic model (Chapter 6)

Let

| | | |
|---|---|---|
| $R$ | = | the number of tags released for a single stock, |
| $S$ | = | the survival rate of tagged fish to the age 2 cohort, |
| $ER$ | = | the fishery brood ER, |
| $s$ | = | the fishery sampling rate, |
| $T$ | = | the number of tags recovered in the fishery, |
| $T_0$ | = | the target number of tags desired to be recovered in the fishery, and |
| $\alpha$ | = | the assurance level, i.e. the probability that at least $T_0$ tags will be recovered. |

Assume that tags are independent so that $T$ is a binomial random variable where each released tag has the same probability of being recovered in the fishery ($p = S*ER*s$). If $T_0$ is the target number of tags to be recovered in the fishery to meet precision criteria, then

$$P(T \geq T_0) = 1 - P(T < T_0) \cong 1 - P\left(Z < \frac{T_0 - Rp}{\sqrt{Rp(1-p)}}\right)$$

so that

$$P(T \geq T_0) = \alpha \Rightarrow P\left(Z < \frac{T_0 - Rp}{\sqrt{Rp(1-p)}}\right) = 1 - \alpha \Rightarrow$$

$$\frac{T_0 - Rp}{\sqrt{Rp(1-p)}} = \Phi^{-1}(1-\alpha).$$

where $\Phi^{-1}$ is the inverse of the standard normal cumulative density function.

From this we get the quadratic equation:

$$(T_0 - Rp)^2 = \left[\Phi^{-1}(1-\alpha)\right]^2 Rp(1-p) \Rightarrow$$
$$T_0^2 + R^2p^2 - 2T_0Rp - \left[\Phi^{-1}(1-\alpha)\right]^2 Rp + \left[\Phi^{-1}(1-\alpha)\right]^2 Rp^2 = 0$$

This equation can be solved for tagging level (release numbers $R$) given some recovery rate $p$, or it can be solved for the necessary recovery rate $p$ given some release number $R$. In the second case, once $p$ is determined, it can be used to solve for the appropriate sampling rate ($s$) given an expected survival and ER.

**Tagging Level**

Given a tag recovery rate $p = S*ER*s$, the following equation can be solved for the necessary tagging release level for a single stock:

$$R^2p^2 - 2T_0Rp - \left[\Phi^{-1}(1-\alpha)\right]^2 Rp + \left[\Phi^{-1}(1-\alpha)\right]^2 Rp^2 + T_0^2 =$$
$$R^2p^2 + R\left(\left[\Phi^{-1}(1-\alpha)\right]^2 p^2 - 2T_0p - \left[\Phi^{-1}(1-\alpha)\right]^2 p\right) + T_0^2 \Rightarrow$$

$$R = \frac{-\left(\left[\Phi^{-1}(1-\alpha)\right]^2 p^2 - 2T_0p - \left[\Phi^{-1}(1-\alpha)\right]^2 p\right) \pm \sqrt{\left(\left[\Phi^{-1}(1-\alpha)\right]^2 p^2 - 2T_0p - \left[\Phi^{-1}(1-\alpha)\right]^2 p\right)^2 - 4p^2T_0^2}}{2p^2}.$$

**Sampling Level**

Given a certain tagging level, the following equation can be solved for the necessary sampling rate for an expected survival and ERs:

$$R^2p^2 - 2T_0Rp - \left[\Phi^{-1}(1-\alpha)\right]^2 Rp + \left[\Phi^{-1}(1-\alpha)\right]^2 Rp^2 + T_0^2$$

$$= p^2\left(R^2 + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right) - p\left(2T_0R + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right) + T_0^2 \Rightarrow$$

$$p = \frac{\left(2T_0R + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right) \pm \sqrt{\left(\left(2T_0R + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right)\right)^2 - 4\left(R^2 + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right)T_0^2}}{2\left(R^2 + \left[\Phi^{-1}(1-\alpha)\right]^2 R\right)}$$

with

$$s = \frac{p}{S * ER}.$$

In both cases, for the tagging level and the sampling rate, the positive root provides the correct solution. Figure 6-4 shows sampling rates necessary given a 200,000 release size for different exploitation and survival rates.

**Using Tool to Minimize Cost**

Given an assurance level $\alpha$, an expected survival $S$ and ER $ER$, one can use the above equations to identify the tagging/sampling needs that will minimize the cost to achieve $\alpha$. To see this, one can optimize on either the sampling rate $s$ or on the tagging rate $R$ since either can be written as a function of the other. Let $R$ be written as a function of $s$, $s = f(R)$. Then if the costs can be identified per unit of tagging and sampling, say $C_R$ and $C_s$, the total cost for any combination of $R$ and $s$ for a single tag group and fishery is:

$$C = BT + C_R*(R - BSR)*100 + BS + C_s*(s - BSs)*100$$
$$= BT + C_R*(R - BSR)*100 + BS + C_s*(f(R) - BSs)*100$$

where

| | | |
|---|---|---|
| $C$ | = | total cost |
| $BT$ | = | baseline cost of tagging program (equipment, minimum staff, etc.) |
| $C_R$ | = | cost per tag |

| | | |
|---|---|---|
| $R$ | = | number of tags |
| $BSR$ | = | number of tags included in baseline cost of tagging program |
| $BS$ | = | baseline cost of sampling program for minimum sampling rate |
| $C_s$ | = | cost per additional sampling rate unit |
| $s$ | = | desired sampling rate |
| $BSs$ | = | sampling rate covered by baseline cost of sampling program. |

Finding the tagging level that minimizes the square of this function that will minimize the cost is the solution to:

$$\frac{d}{dR}(C)^2 = 0.$$

Solving this equation for $R$ will yield the optimum tagging rate and through the function $s=f(R)$ the optimum tagging/sampling rate combination.

This tool can be used with multiple fisheries and multiple stocks by expanding the cost equation. A simple but general-purpose expansion might be created under the assumption that the costs are the same for a number of stocks and fisheries.

$$C = (BT+C_R*(R-BSR)*100)*(\text{\# of stocks}) + (BS + C_s*(f(R)-BSs)*100)*(\text{\# of fisheries}).$$

# Appendix D. Summary of Indicator Stocks

## D.1 PSC Indicator Stock Program

The PST specified that the parties maintain an ER indicator stock program to provide the Chinook and Coho technical committees with information from each production area for the annual evaluation of fisheries and to forecast future harvest impacts. The intent was to utilize these indicator stocks to monitor and evaluate the effectiveness of the management measures agreed to by the PSC. The indicator stock programs provide information needed for cohort and ER analyses for wild and hatchery coho and Chinook salmon.

In 1985, the CTC and CoTC of the PSC initiated the Chinook and Coho indicator stock programs. Stocks that were representative of particular basins, MUs, or the larger production regions were to be included in the programs based upon the following guidelines. ER indicator stocks were to be chosen based on the following criteria (Morishima 1986):

1) In aggregate, their ability to represent all major regions and racial types of interest to the PSC;
2) The stock must be sufficiently abundant and easily tagged so that the agency responsible can make a long-term commitment for tagging the stock;
3) The agency responsible for tagging the stock must make a commitment to sample and estimate the escapement of tagged fish and report the results to the PSMFC in a timely manner.
4) Reliable estimates of catch and escapement must be available.

The first characteristic reflects the emphasis of PSC management on the conservation of wild stocks of Chinook and coho salmon. The major issue regarding the use of CWTs for this purpose is the selection of CWT release groups that have exploitation patterns that represent populations of interest. Because of the cost and logistical issues of tagging and recovering sufficient numbers of wild smolts, the usual practice is to apply CWTs to groups of hatchery fish from appropriate brood stocks and release strategies and use these groups as surrogates to estimate impacts on natural stocks of interest.

For Chinook salmon the CTC uses a set of indicator stocks, which have been consistently tagged over long time series, and which have a standard target tagging level of approximately 200K per year. No formal system of indicator stocks has been established by the CoTC, although for Puget Sound and Washington coastal stocks tagging group standards are set at 40 and 75K. The CoTC uses any tagged coho released within a production region that meets specified criteria in procedures that generate contribution estimates for natural production from geographic regions.

The key assumption underlying PSC regimes that the selected hatchery indicator stocks are representative of their associated natural stocks is difficult to assess. Because of the difficulty of tagging and recovering sufficient numbers of naturally produced fish, direct validation of this assumption through CWT methods can be difficult and costly. Currently, fishery managers

largely rely upon CWT releases from hatcheries to estimate fishery impacts on associated wild stocks, except for 7 wild Chinook stocks coastwide and 12 wild coho stocks in SEAK.

The CWT Workgroup was tasked with the responsibility of collating available information relating to the distribution patterns of wild and hatchery fish.

**RECOMMENDATION 4** – *We recommend completion of a comprehensive survey and statistical analysis of all relevant published and unpublished CWT studies that concerns the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts. This review should also include new analysis of relevant agency-collected data that have not yet been previously subject to analysis. Recommendations for additional studies should be made if they are judged necessary.*

Workgroup Tasks

3) Summarize the results from all the relevant management agencies' published and unpublished CWT studies that concern the correspondence between exploitation patterns and rates for hatchery indicator stocks as compared to their natural counterparts.
4) Review current indicator stock coverage and provide recommendations where additional analysis could be conducted for peer review that would advance understanding of the relationship between hatchery indicator stocks and their natural counterparts.

The workgroup did not have the time to examine the issue of correspondence of hatchery and wild fish to any degree. The Expert Panel in their report (Hankin et.al. 2005) provided a survey of existing published results and some agency information. Additional information regarding coho salmon from the CoTC is provided below, plus one comparison of three years of hatchery vs. wild ERs and marine survival. Additional studies can be completed with existing or new data for coho in some geographic areas of the Pacific coast. Additional studies regarding this topic for Chinook salmon are underway in Alaska, Canada, and the Columbia River and on the Oregon Coast. The results of these efforts for both species will be compiled and reported in the future.

## D.2 Correspondence between Exploitation Patterns and Rates for Hatchery Indicator Stocks as Compared to Their Natural Counterparts

The CWT Expert Panel has reported that available information indicates that the assumption that hatchery stocks can be used as surrogates for natural stocks appears reasonable. Some studies have evaluated the validity of this assumption for coho. The CoTC has performed cluster analyses on several years of CWT recovery data and found that the distribution of hatchery and their corresponding wild stocks among fisheries are very similar. The CoTC relies upon this relationship to generate estimates of production expansion factors for coho MUs. In the Skagit MU, nine years of tagging wild coho smolts provides managers with reasonable comfort that Marblemount Hatchery indicator stock groups adequately represent the fisheries distribution of Skagit wild coho. However, a concern remains over whether the marine survival of wild Baker coho really represents the average wild coho marine survival from the entire Skagit system. In one year, Baker coho were tagged along with tributary-rearing wild coho, and the survival to fisheries of the Baker coho was within the range shown by the other wild coho groups. But, this was a single year study, and the Baker coho are lake-rearing fish, and generally larger than the

typical stream-rearing coho at outmigration. In addition, although the ER and catch distribution of Baker coho are usually very close to that of the Marblemount Hatchery indicator stock, substantial differences have been observed among the return years assessed.

Additional studies of hatchery and wild correspondence have been undertaken in Alaska. Three years of comparisons in published technical reports for a coho hatchery stock near Juneau (DIPAC) and the wild Taku River coho stock support the conclusion of similar ERs (Table D-1). However, the marine survival of the hatchery stock was lower than the wild stock in each of the three years. It is recommended that further analysis of additional years (1996-2004) be compared, along with statistical tests, to determine significance of any differences.

Table D-1. Comparisons of estimated ER for DIPAC hatchery coho salmon releases and Taku River wild coho salmon.

| Adult Run Year | Coho Stock | Estimated ER | Estimated Marine Survival | Citation |
|---|---|---|---|---|
| 1993 | DIPAC Hatchery | 57.1% | 10.0% | McPherson et al. 1994 |
| | Taku River Wild | 50.3% | 17.2% | McPherson et al. 1994 |
| 1994 | DIPAC Hatchery | 69.6% | 17.6% | McPherson and Bernard 1995 |
| | Taku River Wild | 67.3% | 23.0% | McPherson and Bernard 1995 |
| 1995 | DIPAC Hatchery | 58.8% | 6.1% | McPherson and Bernard 1995 |
| | Taku River Wild | 61.6% | 11.9% | McPherson and Bernard 1995 |

### D.3 CWT Indicator Stock Program Coverage

The Workgroup was tasked with evaluating the current indicator program coverage, tagging levels, and compliance with current target levels. Below is a summary of all coho salmon coded-wire-tag indicator programs available coastwide for ER and distribution analyses. The summaries of hatchery and wild stock release levels include brood years (BY) 2002-2004, unless stated otherwise. A similar analysis of the Chinook indicator program was not completed to date.

### D.4 Coho Indicator Stock Program Coverage – Key MUs

In 2002, the PSC adopted the Southern Coho Management Plan pursuant to Annex IV Chapter 5 of the Pacific Salmon Treaty. This plan is directed at the conservation of key MUs (MU), four from Southern British Columbia (Interior Fraser, Lower Fraser, Strait of Georgia Mainland, and Strait of Georgia Vancouver Island), and nine from Washington (Skagit, Stillaguamish, Snohomish, Hood Canal, Strait of Juan de Fuca, Quillayute, Hoh, Queets, and Grays Harbor). Ensuring adequate tagging coverage of each MU coastwide would further the objective of implementing this plan.

In addition to the key MUs listed above, domestic conservation concerns exist for the coho stocks listed under the Endangered Species Act (ESA). Research and monitoring of the distribution, status, and trends of coho have been identified as priority recovery actions needed

for the following evolutionarily significant units (ESU): Lower Columbia River Coho ESU, Southern Oregon/Northern California Coast Coho ESU, and Central California Coast Coho ESU.

In addition to addressing international and domestic conservation concerns, the CWT data supports continued development and implementation of the core fisheries regional planning model, FRAM. The regional planning model used for Coho salmon in the PSC and PFMC management forums depends critically on CWT release and recovery data to represent the distribution and exploitation patterns of individual MUs. To create the model base data the CoTC relies on available CWT recovery data to reconstruct the cohorts to produce estimates of total abundance and fishery impacts for coho MUs coastwide. This requires all MUs caught in pre-terminal fisheries from Southeast Alaska to Central California to be represented by one or more CWT groups.

No formal, coastwide indicator stock program presently exists for coho and all CWT release groups submitted to RMIS are considered for inclusion in the modeling efforts. However, the CoTC made a recommendation in the 1980s that, depending upon average survival rates, 40,000 to 75,000 smolts per ER indicator stock be adipose fin clipped and tagged (Morishima 1986). This recommendation is likely to be re-evaluated by the CoTC, given the lower survival and ER experienced by some stocks in more recent years.

Data from the RMIS database, published reports, and hatchery websites were used to determine recent and proposed annual hatchery production and tagging levels for coho coastwide. Using these data sources, gaps in the CWT program indicators for MUs, or the smaller subregions or subpopulations in some cases, were identified and summarized below.

## D.5 Coho Indicator Stock Program – Data Gaps in Coastwide Coverage

***Representation of Total Production***

Reported coho hatchery production from Southeast Alaska to Central California in recent years has averaged 69.1 million fish per year (BY 2002-2004) (Figure D-1). Of those fish released, approximately 39 million were associated with a tagged fish release group and a total of 4.3 million (6.2%) were coded-wire tagged and adipose-fin clipped. Tagging levels among hatchery facilities varied from 0 to 99.2% of all fish released. However, 76% of all MUs evaluated had tagging rates of 3% or greater during this time period. Currently some important sub regions, such as ESA-listed stocks and those listed in the 1999 PST coho agreement, and even entire MUs are not represented by tagging programs. In addition, many indicator programs for wild stocks, such as the wild stock tagging programs and hatchery DIT programs have recently been discontinued, creating data gaps coastwide. A summary of these data gaps in hatchery and wild indicator coho stock tagging programs is listed in Table D-2 and further summarized below. See Section D.7 for further description of coho indicator programs by MU.

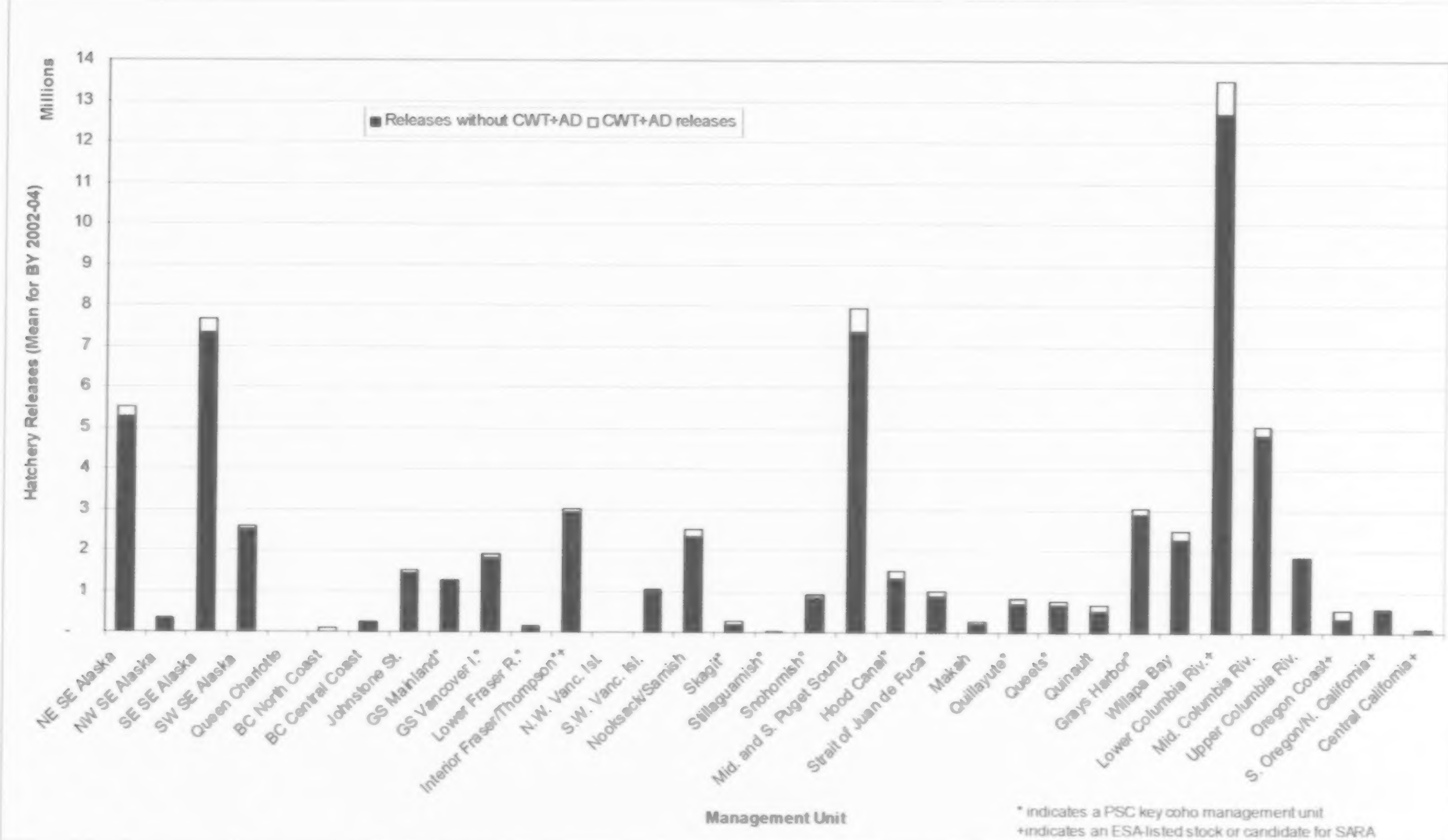


Figure D-1. Mean total number of hatchery coho salmon released annually by MU for brood years 2002-04. Clear bars represent fish released with coded-wire-tags and adipose fin clips (Ad+CWT). Data downloaded from RMIS in August, 2007.

For brood years 2002 through 2004 there are 89 indicator programs available to represent coho hatchery production coastwide. However, the following large geographic MUs do not have any indicator programs: Queen Charlotte, B.C. Central Coast, Georgia Strait Mainland, and Northwest Vancouver Island. Other MUs with one or more current hatchery indicator programs may still need additional programs to represent all hatchery production within the MU. For example, not all hatchery production is represented by tagged fish for all sub-populations of interest within the Upper Fraser River and Southern Oregon/Northern California Coast MUs, both of which are key MUs or stocks of concern. Within the Upper Fraser MU, no indicator programs exist to represent the hatchery production in the North and South Thompson sub-basins. Within the Southern Oregon/Northern California Coast MU, no indicators exist for the production released in northern California. Further assessment of the indicator tag program is needed by the CoTC to determine other gaps in MU subpopulation coverage.

***Representation of Wild Production***

Indicator programs used to represent wild production vary among the regions. Some regions implement wild stock tagging, others have hatchery DIT programs to represent the wild stocks within the region, and some regions have both or only single indicator tagging programs. In southeast Alaska, wild stocks are represented by wild stock tagging in all 4 quadrants (Table D-2). These programs are generally small, ranging from 4,000 to 35,000 tagged and clipped fish released annually; however, given marine survival at 10%, ERs at 30-60%, and precise estimates of escapement, these programs produce statistics sufficiently precise for management. There is concern that because the southern inside sector of Southeast Alaska has only one small wild CWT indicator stock (Hugh Smith) with which to generate all stock parameters, including ERs, the larger aggregation of wild stocks in the southern inside area is not likely well represented by the small CWT indicator. Stocks from Southeast Alaska are not caught in selective fisheries, so no hatchery DIT programs are needed nor implemented in Alaska.

In Canada, due to lack of funding, a number of the wild indicator programs have been cancelled. All but two DIT programs and four wild stock tagging programs in Canada have been discontinued in recent years (Table D-2). Currently, there are no indicator programs of any type in the Queen Charlotte, Georgia Strait Mainland, and Northwest Vancouver Island MUs. In addition, there are no wild stock indicators if the following MUs are exploited in selective fisheries: Queen Charlotte, BC North Coast, Georgia Strait Mainland, and Northwest Vancouver Island MU. Additional tagging may be needed in MUs where single indicator tag groups from hatcheries are used to represent the wild stocks. For example, not all wild subpopulations of interest within the Upper Fraser River MU are represented by an indicator program. Further analyses by the CoTC are needed to determine other gaps in MU wild subpopulation coverage.

In the Puget Sound and Washington Coast regions, wild stocks within all MUs, except the Stillaguamish and Hoh River MUs, are currently represented by hatchery DIT programs and three wild stock tagging programs (Table D-2). Currently, there are no indicator programs in the Stillaguamish and Hoh River MUs and surrogate MUs are used to assess fishery impacts for these stocks. The wild stock tagging programs within the Puget Sound and Washington Coast regions are located within the Skagit River, Hood Canal, and Grays Harbor MUs. All other MUs have hatchery DIT programs to represent the wild stocks. Analyses by the CoTC are needed to determine if additional wild stock tagging or DIT programs within the regions are necessary. For

example, wild stock tagging programs may be proposed for the Stillaguamish and Hoh River MUs if the current surrogate MUs used to assess survival and fishery impacts for these stocks are considered inadequate. Another wild stock tagging program may be warranted in the Skagit system if Baker River natural-origin smolts survive and are exploited in fisheries at a different rate as the rest of the Skagit MU natural-origin smolts. There is also a concern Big Beef Creek wild fish and Hood Canal hatchery DIT fish are exploited in terminal fisheries at a higher rate than the rest of the Hood Canal MU natural-origin smolts. Wild stock tagging or DIT programs may also be needed to represent all racial types within the Quillayute (summer run), Grays Harbor (late run), and Willapa (late run) MUs.

In the Columbia River region, wild stocks are represented by DIT programs in the lower river subregion and by unclipped and tagged hatchery fish in the upper subregion (Table D-2). Currently, there are no wild stock tagging programs in the Columbia River for coho salmon and no DIT programs to represent the Mid-Columbia River wild stocks. Within the Lower Columbia River Subregion, there are four DIT programs, three of which release Type N fish (north turning and early run type) and one that releases Type S fish (south turning and late run type). Further analysis by the CoTC is needed to determine if wild stock tagging or additional DIT programs within the Lower Columbia River Basin are necessary. For example, hatchery tag groups within this subregion may not adequately represent all wild groups of interest, especially in MSFs, and the establishment of wild stock tagging programs may be warranted.

Along the Oregon and California coasts, wild stocks are not well represented. Within the Oregon Coast MU, wild stocks are represented solely by single indicator hatchery tagging programs. Without wild stock tagging or hatchery DIT programs available, no direct estimates of exploitation in mark-selective fisheries are possible for the wild stocks within this MU. In addition, the Lakes subpopulation within this MU is not represented by any indicator program. Wild stocks within the Southern Oregon/Northern California Coast MU are represented solely by a DIT program at Cole Rivers Hatchery on the Rogue River. No indicator tagging programs currently exist in Northern California. There are also no indicator tagging programs in the Central California Coast MU for wild stocks. Small releases of tagged and clipped fish are made from the Warm Springs Hatchery on the Russian River, but the releases are sporadic and the program is not used for ER analysis. Further assessment of the indicator stock coverage for the Oregon and California coast MUs by the CoTC is needed.

### D.6 Coho Indicator Stock Program – Tagging Rates

Given the lower survival and fishery ER experienced by some stocks in more recent years, the most recent tag recovery data need to be assessed by the CoTC and the current tagging level recommendations need to be updated. Assuming the recommendations made in the1980s are still adequate, many current tagging programs have been releasing fewer tagged fish than advised. For example, of the 89 hatchery indicator programs listed in Table D-2, 23 (28%) of these programs have released fewer than 40,000 tagged fish per year in recent years (BY 2002-2004). In addition, many of these hatcheries are located on the Pacific Coast, where the recommendation has been made to release 40,000 to 75,000 tagged fish per release group. Tagging levels among the wild stock indicator programs has been, on average, much smaller than the hatchery indicator programs. Twelve of the 13 wild stock tagging programs currently in operation have released fewer than 40,000 tagged fish per year, on average, in recent years

(Table D-2). The average release size of all wild stock tagging programs currently operating has been approximately 23,000 fish per year per program in recent years.

Table D-2. A summary of wild and hatchery coho salmon indicator tag programs available for each MU from Southeast Alaska to Central California. Recent tagging levels are mean releases of tagged fish from brood years 2002-2004, unless otherwise noted. MUs in bold are Key MUs identified in the Southern Coho Management Plan..

| MU (Code) | MU or Subpopulation | Stock (W = Wild) | Recent Tagging Level | Indicator Needed? |
|---|---|---|---|---|
| Southeast AK | | | | |
| SEAK Northeast Quadrant (NIASKA) | Hatchery | Hidden Falls | 68,000 | No |
| | | Macaulay | 37,000 | |
| | | Port Armstrong | 107,000 | |
| | Wild | Auke Creek (W) | 4,000 | No |
| | | Berners River (W) | 35,000 | |
| | | Chilkat River (W) | 22,000 | |
| | | Slippery Creek (W) | 17,064 | |
| SEAK Northwest Quadrant (NOASKA) | Hatchery | Medvejie Hatchery | 22,000 | Possibly[1] |
| | Wild | Ford Arm Lake (W) | 10,000 | Possibly[1] |
| | | Nakwasina River (W) | 11,000 | |
| SEAK Southeast Quadrant (SIASKA) | Hatchery | Burnett Inlet | 82,000 | No |
| | | Crystal Creek | 27,000 | |
| | | Ketchikan Creek | 34,000 | |
| | | Neets Bay | 10,000 | |
| | | Tamgas | 31,000 | |
| | | Whitman Lake | 166,000 | |
| | Wild | Hugh Smith Lk (W) | 28,000 | Possibly[1,2] |
| SEAK Southwest Quadrant (SOASKA) | Hatchery | Klawock Hatchery | 79,000 | No |
| | Wild | Chuck Creek (W) | 13,000 | Possibly[1] |
| Alaska and B.C. Transboundary Rivers | | | | |
| Alaska and B.C. Transboundary Rivers | Hatchery | no hatchery production | NA | NA |
| | Wild | Taku River (W) | 28,000 | No |
| Canada | | | | |
| Queen Charlotte (QUEENC) | Hatchery | - | - | Yes |
| | Wild | Deena Creek (W) | 21,000 | Yes |
| BC North Coast (BCNCST) | Hatchery | Toboggan Hatchery | 36,000 | Possibly[1] |
| | Wild | Lachmach (Skeena) (W) | discontinued | Yes |
| | | Zoulzap (Nass) (W) | discontinued | |
| | | Slamgeesh (W) | discontinued | |
| BC Central Coast (BCCNTL) | Hatchery | Martin River | discontinued | Yes |
| | Wild | West Arm Cr (W) | 8,000 | No |
| Johnstone Strait (JNSTRT) | Hatchery | Quinsam DIT | 49,000 | No |
| | Wild | Keogh (W) | 17,000 | Possibly[3] |
| | | Quinsam DIT Program | 49,000 | |
| Georgia Strait Mainland (GSMLND) | Hatchery | - | - | Yes |
| | Wild | - | - | Yes |
| Georgia Strait Vancouver Island (GSVNCI) | Hatchery | Big Qualicum | 41,000 | No |
| | | Goldstream | 19,000 | |
| | Wild | Black Creek (W) | 11,000 | No |

| MU (Code) | MU or Subpopulation | Stock (W = Wild) | Recent Tagging Level | Indicator Needed? |
|---|---|---|---|---|
| Upper Fraser River, including Thompson River (FRSUPP) | North Thompson Hatchery | Louis/Lemieux/Dunn | ?? | No |
| | North Thompson Wild | - | - | Yes |
| | South Thompson Hatchery | - | - | Yes |
| | South Thompson Wild | Eagle River (W) | 14,000 | Yes |
| | Lower Thompson/Nicola | Coldwater DIT (Coldwater | 42,000 | No |
| | Lower Thompson/Nicola | Coldwater DIT | discontinued | Yes |
| | Fraser Canyon Hatchery | no hatchery production | NA | NA |
| | Fraser Canyon Wild | - | - | Yes |
| | Upper Fraser Hatchery | no hatchery production | NA | NA |
| | Upper Fraser Wild | - | - | Yes |
| Lower Fraser River (FRSLOW) | Hatchery | Chilliwack | discontinued | Yes |
| | | Inch DIT | 47,000 | Yes |
| | Wild | Inch DIT Program | 40,000 | Possibly[4] |
| Northwest Vancouver Island (NWVNCI) | Hatchery | - | | Yes |
| | Wild | - | | Yes |
| Southwest Vancouver Island (SWVNCI) | Hatchery | Robertson | 40,000 | Yes |
| | Wild | Carnation (W) | discontinued | Yes |
| **Washington** | | | | |
| Nooksack and Sammish Rivers (NOOKSM) | Hatchery | Kendall Creek H. DIT | 47,000 | No |
| | | Lummi Sea Ponds | 43,000 | |
| | | Skookum Creek H. | 43,000 | |
| | Wild | Kendall Creek H. DIT | 47,000 | Possibly[4] |
| Skagit River (SKAGIT) | Hatchery | Cascade River H. DIT | 84,000 | No |
| | Wild | Baker River (W) | 17,000 | Possibly[6] |
| | | Cascade River H. DIT | 44,000 | |
| Stillaguamish River | Hatchery | no hatchery production | NA | NA |
| | Wild | Jim Creek Hatchery (W) | discontinued | Possibly[5] |
| Snohomish River (STILSN) | Hatchery | Tulalip Bay (Bernie | 32,000 | No |
| | | Wallace River H. DIT | 40,000 | |
| | Wild | Wallace River H. DIT | 40,000 | Possibly[4] |
| South Puget Sound (SPGSND) | Hatchery | Soos Creek H. DIT | 45,000 | No |
| | | Puyallup Tribal Hatchery | 66,000 | |
| | | Voights Creek H. DIT | 45,000 | |
| | | South Sound Net Pens | 114,000 | |
| | Wild | Soos Creek H. DIT | 45,000 | Possibly[4] |
| | | Voights Creek H. DIT | 45,000 | |
| Hood Canal (HOODCL) | Hatchery | George Adams H. DIT | 43,000 | No |
| | | Quilcene NFH DIT | 44,000 | |
| | | Pt. Gamble Bay Pens | 60,000 | |
| | | Quilcene Bay Sea Pen | 56,000 | |
| | Wild | Big Beef (W) | 28,000 | Possibly[6] |
| | | George Adams H. DIT | 43,000 | |
| | | Quilcene NFH DIT | 44,000 | |
| Strait of Juan de Fuca (SJDFCA) | Hatchery | Lower Elwha H. DIT | 111,000 | No |
| | | Dungeness H. | discontinued | |
| | Wild | Lower Elwha H. DIT | 68,000 | Possibly[4] |
| Makah (MAKAHC) | Hatchery | Makah NFH DIT | 39,000 | No |
| | Wild | Makah NFH DIT | 38,000 | Possibly[4] |
| Quillayute River (QUILUT) | Fall Run - Hatchery | Solduc H. DIT | 78,000 | No |
| | Fall Run - Wild | Solduc H. DIT | 74,000 | Possibly[4] |

| MU (Code) | MU or Subpopulation | Stock (W = Wild) | Recent Tagging Level | Indicator Needed? |
|---|---|---|---|---|
| | Summer Run - Hatchery | Solduc H. - summer | 43,000 | No |
| | Summer Run - Wild | - | - | Yes |
| Hoh River (HOHRIV) | Hatchery | no hatchery production | NA | NA |
| | Wild | - | | Possibly[5] |
| Queets River (QUEETS) | Hatchery | Salmon R. Fish Cult. DIT | 130,000 | No |
| | Wild | Queets (W) | discontinued | Possibly[4] |
| | | Salmon R. Fish Cult. DIT | 76,000 | |
| Quinault River (QUINLT) | Hatchery | Quinault NFH DIT | 77,000 | No |
| | Wild | Quinault NFH DIT | 82,000 | Possibly[4] |
| Grays Harbor Basin (GRAYHB) | Late Run - Hatchery | Bingham Creek H. - Late | 49,000 | No |
| | | Skookumchuck H - Late[8] | 50,000 | |
| | | Humptulips R. H - Late[8] | 50,000 | |
| | Late Run - Wild | - | - | Possibly[4] |
| | Early Run - Hatchery | Bingham Creek H. DIT - | 85,000 | No |
| | | Skookumchuck H | 50,000 | |
| | | Humptulips R. H[8] | 50,000 | |
| | | Aberdeen Net Pens[8] | 50,000 | |
| | | Friend's Landing Net Pens[8] | 50,000 | |
| | | Lake Aberdeen H[8] | 30,000 | |
| | | Satsop Springs Ponds | 43,000 | |
| | Early Run - Wild | Bingham Creek (W) | 22,000 | No |
| | | Chehalis River (W) | 40,000 | |
| | | Bingham Creek H. DIT | 72,000 | |
| Willapa Basin (WILLAP) | Late Run - Hatchery | Forks Creek H. - late | 48,000 | |
| | Late Run - Wild | - | - | Yes |
| | Early Run - Hatchery | Forks Creek H. DIT | 73,000 | No |
| | | Nemah R. H. | 50,000 | |
| | | Naselle H. | 50,000 | |
| | | Nahcotta Net Pens | discontinued | |
| | Early Run - Wild | Forks Creek H. DIT | 71,000 | Possibly[4] |
| **Columbia River** | | | | |
| Columbia River (COLRIV) | Lower Columbia River - Hatchery Type S (South Turning) and Type N (North Turning) Production | Lewis H. DIT - type S | 70,000 | No |
| | | Lewis H. DIT - type N | 66,000 | |
| | | Sandy H. DIT | 53,000 | |
| | | Eagle Creek NFH DIT | 24,000 | |
| | | North Toutle H. - type S | 30,000 | |
| | | Elochoman H. - type S | 29,000 | |
| | | Elochoman H. - type N | 43,000 | |
| | | Grays River H. - type S | 27,000 | |
| | | Fallert Creek H. - type S | 25,000 | |
| | | Cowlitz Salmon H. - type | 89,000 | |
| | | Kalama Falls H - Type N | 28,000 | |
| | | Klaskanine S.F. Pond | discontinued | |
| | | Deep River Net Pens | 24,000 | |
| | | Cede Youngs Bay Net | 50,000 | |
| | | Oxbow H. | 27,000 | |
| | Lower Columbia River - Wild | Lewis H. DIT - type S | 96,000 | Possibly[4] |
| | | Lewis H. DIT - type N | 69,000 | |
| | | Sandy H. DIT | 26,000 | |
| | | Eagle Creek NFH DIT | 24,000 | |

| MU (Code) | MU or Subpopulation | Stock (W = Wild) | Recent Tagging Level | Indicator Needed? |
|---|---|---|---|---|
| | Mid Columbia River - | Klickitat, Washougal, | 223,000 | No |
| | Mid Columbia River - | - | - | Yes |
| | Upper Columbia River | Cascade, Clearwater, | 999,800 | No[7] |
| **Oregon/California** | | | | |
| Oregon Coast (OREGON) | North Coast - Hatchery | Nehalem H. (N. Coast) | 48,000 | No |
| | | Trask River Ponds | 49,000 | |
| | North Coast - Wild | - | - | Yes |
| | Mid Coast - Hatchery | Salmon River H. (Siletz) | 25,000 | Possibly[1] |
| | Mid Coast - Wild | - | - | Yes |
| | Umpqua - Hatchery | Rock Creek H. (Umpqua) | 48,332 | Possibly[1] |
| | Umpqua - Wild | - | - | Yes |
| | Mid South Coast - Hatchery | Coos Hatchery | 27,000 | Possibly[1] |
| | | Coquille Hatchery | 22,000 | |
| | Mid South Coast - Wild | - | - | Yes |
| | Lakes - Hatchery | no hatchery production | NA | NA |
| | Lakes - Wild | - | - | Yes |
| Southern Oregon and Northern California Coast (ORECAL) | Hatchery | Cole Rivers H. DIT | 27,000 | Possibly[1,4] |
| | | Klamath and Trinity | discontinued | |
| | Wild | Cole Rivers H. DIT | 27,000 | Possibly[4] |
| Central California Coast (CENCAL) | Hatchery | Warm Springs Hatchery | 16,000 | Possibly[1] |
| | Wild | - | - | Possibly[9] |

[1] Tagging levels are low. Further evaluation by the management agency and the Coho Technical Committee is needed to determine if more tagging is necessary to represent this MU.

[2] If escapement was sampled, Chickamin wild could be added as an ER indicator stock (21,000 mean release size).

[3] Wild stock is tagged and ad-clipped. Further evaluation is needed to determine if DIT program in MU adequately represents the wild component of the MU.

[4] No wild stock tagging. Further evaluation is needed to determine if DIT program in MU adequately represents the wild component of the MU.

[5] No wild stock tagging. A surrogate MU is currently used to evaluate fishery impacts on this MU. Further evaluation is needed to determine if DIT program in surrogate MU adequately represents the wild component of the MU.

[6] Wild stock tagging level is low. Further evaluation is needed to determine if DIT program(s) with wild stock tagging in MU adequately represents the wild component of the MU.

[7] Indicator stocks at these facilities are tagged and unclipped.

[8] Iindicator tagging has been implemented after BY 2004 (Future Brood Document 2007).

[9] Not harvested in directed fisheries. Further evaluation by the management agency and the Coho Technical Committee is needed to determine if more tagging is necessary to represent this MU

## D.7 Coho Indicator Program Descriptions by MU

***Southeast Alaska***

In recent years, approximately 16 million coho have been released annually from Southeast Alaska hatcheries. Cohort reconstruction methods used by the Coho Technical Committee currently divide Southeast Alaska coho stocks into 4 quadrants or regions: Northeast, Northwest, Southeast, and Southwest Quadrants. Hatchery tagging levels among the regions have ranged between 3% and 11%. In addition to the hatchery tagging programs, CWT programs used for ER analyses have been implemented for 12 wild stocks throughout the Southeast Alaska. These programs are generally small, ranging from 4,000 to 35,000 tagged and clipped fish released annually; however, given marine sursvival at 10%, ERs at 30-60% and precise estimates of escapement, these programs produce statistics sufficiently precise for mangement. No DIT programs currently exist in Alaska as none are needed.

**Northeast Quadrant (NIASKA)** – Approximately 4.6% of the 5.5 million hatchery coho released are CWT'd and adipose fin clipped. In addition to the hatchery programs, there are four wild stock tagging programs implemented in this region. These include the Auke Creek, Berners River, Chilkat River, and Slippery Creek programs, which ranged in size from 4,000 to 35,000 tagged and clipped fish released annually.

**Northwest Quadrant (NOASKA)** – Medvejie is the only hatchery production in the region. Approximately 35,000 (10.5%) of the 329,000 fish released annually from this hatchery were tagged and clipped in recent years. Two wild stock tagging programs exist in this region. These include the Ford Arm Lake (BY 2003-2004 only) and Nakwasina River programs which have released in recent years approximately 10,000 and 11,000 tagged fish annually, respectively.

**Southeast Quadrant (SIASKA)** – Approximately 340,000 (4.5%) of the 7.7 million hatchery coho released are CWT'd and adipose fin clipped. In this region the wild stock tagging program in the Hugh Smith Lake system where an average of 28,000 tagged fish have been released annually in recent years is used for ER analyses (ER). The wild stock tagging program on the Chickamin River, where 22,000 tagged and clipped fish are released annually on average, could also be used for ER analyses if escapement estimates were made for this program.

**Southwest Quadrant (SOASKA)** – Klawock is the only hatchery production in the region. Approximately 79,000 (3%) of the 2.6 million hatchery coho released are CWT'd and adipose fin clipped. This tagging program is used for stock distribution assessment only because data on terminal catch and escapement are poor. In addition to the hatchery program, a wild stock tagging program is implemented on Chuck Creek where recent releases have averaged approximately 13,000 tagged fish annually.

**Alaska and British Columbia Transboundary Rivers (TRANAC)** – No hatchery production exists in this region. A wild stock tagging program used for ER analyses is implemented in the Taku River basin. An average of 28,000 tagged and clipped fish were released annually in recent years. The wild stock tagging program on the Stikine River where 20,000 tagged and clipped fish are released annually on average, could also be used in ER analyses if escapement estimates were made for this program.

***British Columbia***
In recent years, approximately 9.3 million coho have been released annually from British Columbia hatcheries. For brood years 2002-2004, hatchery tagging levels among the MUs have ranged between 0% and 97%, but many tagging programs have been recently discontinued. Currently, three MUs are lacking ER indicator stock programs. In addition, of the nine wild coho stock tagging programs that operated in the late 1990's, only four remain in existence.

The Southern Coho Management Plan adopted by the Pacific Salmon Commission pursuant to the 1999 Pacific Salmon Treaty Agreement defines 4 key natural-origin coho MUs (MUs) in British Columbia where the Parties agree to develop management measures and programs to prevent further decline in spawning escapements, adjust fishing patterns, and initiate, develop, or improve management programs for these stocks. These MUs include Upper Fraser River (FRSUPP), Lower Fraser River (FRSLOW), Georgia Strait Mainland (GSMLD), and Georgia Strait/Vancouver Island (GSVCI) (PSC 2004). Exploitation rate indicator programs do not currently exist for most of the Upper Fraser River MU and all of the Georgia Strait Mainland MU.

**Queen Charlotte Islands MU (QUEENC)** – Coho releases within this MU have been reduced from approximately 695,000 annually for BY 2000-2001 to 10,000 for BY 2003. No hatchery tagging programs currently exists, but a tagging program has been reinstated on wild coho in Deena Creek.

**B.C. North Coast (BCNCST)** – Hatchery Production in the North Coast MU has been much reduced in recent years from approximately 476,000 fish released annually for BYs 2000 and 2001 to approximately 89,000 released for BYs 2002 to 2004. A total of 86,000 of these fish released annually were tagged and ad-clipped. The Toboggan Hatchery stock is the only hatchery ER indicator program currently implemented in the region, where, on average, 36,000 tagged and clipped fish were released annually in recent years. The Fort Babine Hatchery tagging program has been used for distributional analyses, but this program was discontinued with BY 2002. Wild stock tagging of the Zolzap, Lachmach, and Slamgeesh stocks within the region have also been discontinued recently and there are no DIT programs implemented in the region.

**B.C. Central Coast (BCCNTL)** – Hatchery Production in the Central Coast MU has been much reduced in recent years from approximately 481,000 fish released for BYs 2002 to 15,000 for BY 2003. No hatchery fish were recorded in RMIS to have been released into this MU for BY 2004. The Snootli, Kitimat, and Heiltsuk stock tagging programs have been used for distributional analyses, but all hatchery tagging programs in this MU have been recently discontinued. An indicator program on the Martin River is currently under consideration (Riddell 2004). A wild stock indicator program is still in operation on West Arm Creek, where approximately 8,000 tagged and clipped fish have been released annually in recent years.

**Johnstone Strait (JNSTRT)** – Approximately 1.5 million coho have been released annually from hatcheries in the Johnstone Strait MU in recent years. Hatchery production includes releases from Port Hardy, Kokish, Woss Community, and Quinsam Hatchery programs. The

Johnstone Strait MU is represented by a DIT indicator program at Quinsam Hatchery, where recent releases have averaged 49,000 tagged fish annually (each DIT group). In addition, a wild stock indicator program has been implemented for the Keogh stock, where approximately 14,000 fish from BY 2002 and 2003 each were tagged and released without adipose fin clips. The Keogh River indicator program was changed for BY 2004, where 24,000 fish were tagged and released with adipose fin clips. Incomplete escapement sampling has impacted both the hatchery and wild stock indicator programs in existence.

**Georgia Strait Mainland (GSMLND)** – Approximately 1.3 million coho have been released annually from 11 hatchery programs in the Georgia Strait Mainland MU in recent years, but no indicator programs currently exist.

**Georgia Strait Vancouver Island (GSVNCI)** – Approximately 1.9 million hatchery coho have been released annually from hatcheries in the Georgia Strait/Vancouver Island MU in recent years. Single indicator tagging programs exists for the Big Qualicum River Hatchery and Goldstream River Hatchery stocks. Big Qualicum has had average annual release sizes of 41,000 tagged and clipped fish in recent years. Approximately 19,000 tagged and clipped fish have been released from Goldstream River Hatchery in recent years. DIT programs were discontinued at both of these facilities after BY 2002. The Puntledge Hatchery indicator program was discontinued after BY 2002.

A wild stock tagging program exists on Black Creek, where approximately 11,000 fish were tagged each year. Tagging of wild coho salmon smolts began at Black Creek in 1976. The stock represents the freshwater survival, marine survival, and fishery impacts of wild coho salmon in the Georgia Strait, east coast Vancouver Island region. The tagged fraction of the freshwater production is estimated the following year by sampling mark rates in the adult escapement program.

**Upper Fraser River, including Thompson River (FRSUPP)** – In 2002, Interior Fraser River coho salmon (IFC), which includes the upper Fraser River and Thompson River, were recognized as a 'species' under the Species At Risk Act (SARA) and designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Studies of the genetic structure of this MU indicate that there are five subpopulations; three within the Thompson (North Thompson, South Thompson, and Lower Thompson/Nicola regions) and two within the Fraser (the area between the Fraser Canyon and the Thompson-Fraser confluence, and the Fraser River and tributaries above the Thompson-Fraser confluence).

Hatchery production in the Upper Fraser River MU has declined from approximately 1 million fish each from brood years 2000 and 2001 to 164,000 fish released annually in more recent years. An indicator program at the Spius Creek Hatchery, where approximately 40,000 tagged and clipped fish have been released annually in recent years, is currently implemented in the Lower Thompson/Nicola subregion. Incomplete escapement sampling has impacted this hatchery indicator program. A DIT program at this facility was discontinued after the 2002 brood. Other hatchery tagging programs on Louis, Lemieux, and Dunn Creek stocks, located within the North Thompson subregion have been used for analysis of stock distribution.

Early estimates of exploitation of this MU were based on catches and escapements of coded-wire tagged hatchery coho. More recent analyses (1998-2000), where CWT data were inadequate, have been completed using a DNA based approach. Interior Fraser/Thompson coho have been found to be sufficiently distinct genetically to allow estimation of numbers of fish caught using a DNA-based approach (DFO 2002). Specifically, stock identification estimates by catch area have been applied to estimates of coho encounters. Historically, estimates of marine survival for IFC hatchery stocks are limited to the North and South Thompson, and are not consistently available for a sufficient number of years to be a reliable time series. Therefore, annual average marine survival rates for two Strait of Georgia wild indicator stocks have been used as a survival index for IFC.

**Lower Fraser River (FRSLOW)** – Approximately 3 million hatchery coho have been released within the Lower Fraser River MU annually in recent years. One tagging program is currently implemented in this MU. It is the DIT program at Inch Creek Hatchery, where release sizes have averaged approximately 46,000 for the CWT+AD group and 40,000 for the CWT only group over the 2002-2004 broods. The indicator tag program at Chilliwack Hatchery, which was impacted by incomplete escapement sampling, was discontinued after the 2002 brood.

**Northwest Vancouver Island (NWVNCI)** – Recent hatchery production in this MU has been reduced from approximately 800,000 (BY 2000 and 2001) to 7,500 hatchery coho per year (BY 2003-2004). No hatchery or wild stock indicator programs exist in the Northwest Vancouver Island MU.

**Southwest Vancouver Island (SWVNCI)** – Approximately 1 million hatchery coho have been released within this MU annually in recent years. This region is represented by the Robertson Creek Hatchery index program, where annual release sizes have been approximately 40,000 tagged and clipped fish in recent years. Annual counts of returning salmon are made at the Stamp Falls fishway downstream of the hatchery and escapement to the hatchery is also estimated. The DIT program at this facility was discontinued after the 2002 brood. Coded wire tagging of wild coho smolts at Kirby Creek began in 1999 and at Carnation Creek in 2001, but these programs have been discontinued.

***Washington***

The Southern Coho Management Plan adopted by the Pacific Salmon Commission pursuant to the 1999 Pacific Salmon Treaty Agreement defines 9 key natural-origin coho MUs in Washington where the Parties agree to develop management measures and programs to prevent further decline in spawning escapements, adjust fishing patterns, and initiate, develop, or improve management programs for these stocks. These MUs include Skagit, Stillaguamish, Snohomish, Hood Canal, Strait of Juan de Fuca, Quillayute, Hoh, Queets, and Grays Harbor (PSC 2004). Indicator tag programs for Washington stocks were summarized using releases recorded in RMIS (downloaded August 2007) and the draft 2007 Future Brood Document.

**Puget Sound and Strait of Juan de Fuca (Washington)**

All naturally spawned populations of coho salmon in Puget Sound, Hood Canal, and the eastern Olympic Peninsula (east of Salt Creek) are included in the Puget Sound/Strait of Georgia ESU which was classified as a Species of Concern in April 2004 due to specific risk factors (Federal

Register Notice: 69 FR 19976 [April 15, 2004]). This ESU includes the following coho MUs: Nooksack/Samish, Skagit, Stillaguamish, Snohomish, South Puget Sound, Hood Canal, and Strait of Juan de Fuca.

**Nooksack/Samish MU (NOOKSM)** – Approximately 2.5 million hatchery fish were released into this MU annually in recent years. Tag indicator programs for this MU include the DIT program at Kendall Creek hatchery that has a goal of releasing 45,000 tagged fish in each group, and the single indicator tag programs at Skookum Creek and Lummi Sea Ponds which have a goal of releasing 50,000 tagged and clipped fish each.

**Skagit River MU (SKAGIT)** – Approximately 280,000 hatchery fish were released into this MU annually in recent years. Survival and ER estimates of this MU are derived using CWT data from the Cascade River Hatchery (AKA Marblemount) and Baker River Wild coho tagging programs. The Cascade River Hatchery employs a DIT program with a goal of 45,000 tagged fish in each group; therefore, providing the non-ad clipped+CWT coho as surrogates to estimate exploitation of natural-origin coho from this MU

**Stillaguamish MU (STILSN)** – There have been no harvest-oriented hatchery coho release programs implemented in the Stillaguamish River basin. Only one small CWT tagging program, the Stillaguamish Tribe's wild stock enhancement program, has been conducted in recent years (prior to BY 2002). Approximately 5,000 fish were tagged and released per year, but there are no direct estimates of marine survival or exploitation for this MU due to the limited numbers of CWTs released from the enhancement project, and lack of formal escapement accounting for the returning tagged coho. The CWT tagging program ended with BY 1998 and the enhancement program was suspended in 2004, pending review. In the recent development of the FRAM base period, CWT data from the indicator stocks in the Snohomish MU are used as surrogates for assessing pre-terminal fishery exploitation patterns and rates for the Stillaguamish MU.

**Snohomish MU (STILSN)** – Hatchery releases in this MU in recent years has averaged 920,000 coho annually. Hatchery production is represented by Tulalip Bay and Wallace River hatchery programs. The Tulalip Bay indicator program has released approximately 32,000 tagged fish in recent years, but the current goal is to release 50,000 tagged fish in the future. The Wallace Hatchery CWT release is a DIT program with a goal of 45,000 tagged fish to be released of each group. Survival rates are estimated using both hatchery programs, while the Wallace program provides a means for ER analysis. There is incomplete accounting of tagged coho escapement at the Tulalip Hatchery. Annual estimates of marine survival for Snohomish River natural-origin coho are made using the total number of adults returning to the Sunset Falls Fishway, annual estimates of adult ocean recruitment using fishery exploitation values derived from the Wallace River Hatchery CWT data, and predicted parent smolt production for the watershed above the falls. The smolt production predictions are based upon smolt monitoring studies conducted by WDFW at Sunset Falls in the in the mid-1980s. Exploitation rate values for the non-ad clipped+CWT coho from Wallace Hatchery provide a surrogate measure of exploitation for natural origin coho in this MU.

**South Puget Sound MU (SPGSND)** – Hatchery releases in the South and mid Puget Sound region have averaged approximately 7.9 million coho annually in recent years. Mid Puget

Sound hatchery production is represented by the Soos Creek, Voights Creek, and Puyallup Tribal hatchery programs. The Soos Creek and Voights Creek hatchery CWT releases are DIT programs with a goal of 45,000 tagged fish to be released of each group at each facility. Exploitation rate values for the non-ad clipped+CWT coho from these hatchery provide a surrogate measure of exploitation for natural origin coho in this MU. The release goal at the Puyallup Tribal Hatchery is 100,000 tagged and clipped fish. In South Sound the hatchery production has averaged 4.3 million coho per year. This subregion is represented by the South Sound Net Pen indicator program, where the release goal is 50,000 tagged and clipped coho per year. In addition to the ER indicator programs listed above, other CWT programs within the MU are used for distributional analyses. These include the tagging programs implemented in the Lake Washington and Duwamish River basins, the mid Puget Sound Net Pens, Kennedy Creek, and the Nisqually River.

**Hood Canal MU (HOODCL)** – Hatchery production in this MU has been approximately 1.5 million coho annually in recent years. Hatchery production is currently represented by the DIT programs at Big Quilcene National Fish Hatchery (QNFH) and George Adams Hatchery. CWT recovery-based estimates of exploitation and survival rates are available for these hatchery programs. Survival rate estimates are also available for the Port Gamble Net Pen and Quilcene Bay Net Pen production. All hatchery indicator programs have a release goal of 45,000 tagged coho from each group, except for QNFH, which has a release goal of 50,000 tagged fish of each DIT component. Wild coho survival and ER are monitored by natural-origin CWT marked coho from the WDFW Big Beef Creek Research Station. Recent releases from this station have averaged 28,000 tagged wild coho annually. There is concern Big Beef Creek wild fish and non-ad clipped+CWT coho from the hatchery programs are exploited in terminal fisheries at a higher rate than the rest of the Hood Canal MU natural-origin smolts.

**Strait of Juan de Fuca MU (SJDFCA)** – Approximately 1 million hatchery coho salmon have been released into this MU annually in recent years. CWT recovery-based estimates of exploitation and survival rates are available for the Lower Elwha Hatchery Program. The Lower Elwha Hatchery utilizes a DIT program where ER values for the non-ad clipped+CWT coho from this program provide a surrogate measure of non-terminal exploitation for natural-origin coho from this region. This program has a release goal of 75,000 tagged fish of each DIT component. The Dungeness River Hatchery program has also been tagged periodically in the past, but the last CWT releases from this facility were BY 2004 releases.

**Olympic Peninsula (West of the Elwha River) and Washington Coast**

The coastal region includes the Olympic Peninsula and Southwest Washington coho salmon ESUs. The Olympic Peninsula ESU includes all naturally spawned populations of coho salmon in Washington coastal rivers and streams from Point Grenville, which is south of the Quinault River, north to and including Salt Creek (west of the Elwha River). This ESU includes the Makah, Quillayute, Hoh, Queets, and Quinault MUs. Listing of this ESU under the ESA was determined to be not warranted in 1995 (60 FR 38011 [July 25, 1995]). Approximately 2.6 million hatchery coho have been released annually into this ESU in recent years.

The Southwest Washington coho ESU includes all naturally spawned populations of coho salmon from coastal drainages in southwest Washington between the Columbia River and Point

Grenville. This ESU includes the Grays Harbor and Willapa MUs. The status of this ESU under the ESA is currently classified as Undetermined. Approximately 5.5 million hatchery coho have been released annually into this ESU in recent years.

**Makah MU (MAKAHC)** – Approximately 260,000 hatchery coho have been released annually into the Sooes River in this MU in recent years. Hatchery and wild production in this MU is represented by a DIT program at the Makah National Fish Hatchery, where the goal is to release 40,000 tagged fish of each DIT component.

**Quillayute River MU (QUILUT)** – Approximately 820,000 hatchery coho have been released into this MU annually in recent years. The Quillayute River MU has two unique populations of coho, a *summer* coho run, and a *fall* coho run. The Sol Duc Hatchery releases both summer and fall runs of CW-tagged coho. A DIT program for the fall run was employed with brood year's 2002 and 2003, with a goal of releasing 75,000 tagged fish of each DIT component. The indicator program for the summer run has a goal of releasing 50,000 tagged and clipped fish. No CWT recovery-based estimates of survival and ER are available for the 1993 to 2002 brood years due to unreported terminal fishery CWT recovery data. This fishery is a major portion of the total harvest for this population.

**Hoh River MU (HOHRIV)** – There is currently no hatchery coho production or a CWT program present in this MU. The Queets River MU tagging program is used as a surrogate to estimate pre-terminal fishery ER.

**Queets River MU (QUEETS)** – Approximately 780,000 hatchery coho have been released into this MU annually in recent years. CWT recovery-based estimates of survival and ER are available for the Salmon River Hatchery program. This program is a DIT program, with a release goal of 75,000 fish each DIT component; thus, pre-terminal ER estimates for the non-ad clipped+CWT coho provide a surrogate measure of exploitation for natural-origin coho in this MU. Salmon River Hatchery coho return earlier than the Queets wild population, resulting in terminal fishery ER are that are higher on Salmon River Hatchery coho than the wild coho. No CWT recovery-based estimates of survival and ER are available for the 1999, 2000, and 2002 brood years due to incomplete escapement accounting in the RMIS database. A natural production enhancement program, where natural-origin juveniles were periodically reared, CWT'd, and released unclipped at several locations has been operated by the Quinault Tribe in the basin. This program was suspended after the 2004 brood year, pending review of the project results to date and future coho management objectives for this MU.

**Quinault River MU (QUINLT)** – Approximately 680,000 hatchery coho have been released into the Quinault River MU annually in recent years. Hatchery coho production in this MU is represented by the DIT program implemented at the Quinault National Fish Hatchery. The release goal of the program is 80,000 tagged fish of each DIT component. Pre-terminal ER estimates for the non-ad clipped+CWT coho also provide a surrogate measure of exploitation for natural-origin coho in this MU.

**Grays Harbor MU (GRAYHB)** – The Grays Harbor MU has an early and late run of coho salmon. Recent hatchery production has averaged 3 million coho total annually. This includes production by Humptulips (Steven Creek), Bingham Creek (Satsop River), and Lake Aberdeen

Hatcheries and a number of net pen operations. CWT recovery-based exploitation and survival rate estimates are available for the Bingham Creek early and late run programs. The early run tagging program is a DIT program with a release goal of 75,000 tagged fish of each DIT component. The release goal for the late run tagging program is 50,000 tagged and clipped fish. Wild coho survival and ER are monitored by natural-origin CWT marked coho from the WDFW Bingham Creek Research Station, where an average of 22,000 tagged and unclipped fish have been released annually in recent years. Another wild stock tagging program is implemented in the upper Chehalis River, where approximately 40,000 tagged and unclipped fish have been released annually in recent years. In addition to the ER indicator programs listed above, other CWT programs within the MU are used for distributional analyses. These include the tagging programs implemented at the Skookumchuck Hatchery (late and early run), and Friend's Landing and Aberdeen net pen operations (early run programs).

**Willapa Basin MU (WILLAP)** – The Willapa Basin MU has early and late runs of coho salmon. Approximately 2.5 million hatchery coho total were released into this MU annually in recent years. The early run production is represented by a DIT program at Forks Creek Hatchery and single indicator programs at Nemah River and Naselle hatcheries, and the Nahcotta Net Pen operation. A single indicator tag program for the late run is also implemented at Forks Creek Hatchery.

**Columbia River MU (COLRIV)** – The Columbia River Basin is split into the following three subregions for coho salmon management: Snake River/Upper Columba River, Mid Columbia River, and Lower Columbia River subregions. Approximately 20.4 million hatchery coho were reported to have been released annually in the entire Columbia River Basin in recent years. Of these, approximately 1 million were tagged. There are currently no wild stock tagging programs in the Columbia River.

Approximately 1.8 million hatchery coho from the Cascade, Clearwater, Kooskia, Leavenworth, Willard, and Winthrop hatcheries were released annually in the upper subregion in recent years. Approximately 1 million of these were released tagged and unclipped. No tagged and clipped hatchery coho have been released from this subregion in recent years.

In the Mid Columbia subregion, approximately 5 million hatchery fish from the Klickitat, Washougal, Willard, and Cascade hatcheries have been released annually in recent years. This subregion's hatchery program is expected to be represented by approximately 145,000 tagged and clipped fish from the Klickitat, Washougal, and Cascade hatcheries in the future. The DIT program at Willard National Fish Hatchery was discontinued after the 2002 brood.

The Lower Columbia River subregion encompasses the Lower Columbia River ESU. Lower Columbia River coho were identified as a separate ESU from the Southwest Washington ESU and were listed as threatened in June 2005 (70 FR 37160). This ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries in Washington and Oregon, from the mouth of the Columbia up to and including the Big White Salmon and Hood Rivers, and includes the Willamette River to Willamette Falls, Oregon, as well as twenty-five artificial propagation programs: the Grays River, Sea Resources Hatchery, Peterson Coho Project, Big Creek Hatchery, Astoria High School (STEP) Coho Program, Warrenton High

School (STEP) Coho Program, Elochoman Type-S Coho Program, Elochoman Type-N Coho Program, Cathlamet High School FFA Type-N Coho Program, Cowlitz Type-N Coho Program in the Upper and Lower Cowlitz Rivers, Cowlitz Game and Anglers Coho Program, Friends of the Cowlitz Coho Program, North Fork Toutle River Hatchery, Kalama River Type-N Coho Program, Kalama River Type-S Coho Program, Washougal Hatchery Type-N Coho Program, Lewis River Type-N Coho Program, Lewis River Type-S Coho Program, Fish First Wild Coho Program, Fish First Type-N Coho Program, Syverson Project Type-N Coho Program, Eagle Creek National Fish Hatchery, Sandy Hatchery, and the Bonneville/Cascade/Oxbow complex coho hatchery programs. Populations that are Type-N predominantly head north once they outmigrate to the ocean, while Type-S populations predominantly turn south upon exiting the Columbia River.

In the Lower Columbia River subregion, approximately 13.5 million hatchery coho were released annually from production facilities in recent years. Of these, 780,000 were CWTd and clipped. CWT recovery-based exploitation and survival rate estimates are available for the Lewis Hatchery (Type-S and Type-N), Sandy River, and Eagle Creek National Fish Hatchery (NFH) DIT programs. The Lewis Hatchery tagging program has a release goal of 75,000 tagged fish of each DIT component of each run type. The Sandy River and Eagle Creek NFH tagging programs each have a release goal of 25,000 tagged fish of each DIT component. In addition to the ER indicator programs listed above, other CWT programs within the MU are used for distributional analyses. These include the tagging programs implemented at the North Toutle, Elochoman, Grays River, Kalama Falls, and Oxbow hatcheries, and the Deep River and Youngs Bay Net Pen operations.

***Oregon and California***

**Oregon Coast MU (OREGON)** – This region is represented by the Oregon Coast ESU, which is currently not listed under the ESA. This ESU includes all naturally spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco, as well as five artificial propagation programs: the North Umpqua River, Cow Creek, Coos Basin, Coquille River, and North Fork Nehalem River coho hatchery programs. This ESU is split into five geographical strata for assessment (Chilcote et al. 2005). These include North Coast, Mid Coast, Umpqua, Mid South Coast, and the Coastal Lakes subregions. In recent years, approximately 550,000 coho have been released annually from this ESU. Hatchery tagging levels among the subregions have ranged between 12% and 54%. No wild stock tagging programs or DIT programs are currently implemented in the Oregon Coast MU.

The North Coast subregion includes the North Fork Nehalem and Trask River Hatchery tagging programs, where approximately 48,000 tagged and clipped fish have been released in recent years from each facility, annually (BY 2000-2003). Hatchery production in the Mid Coast subregion is represented by the Siletz Hatchery tagging program where approximately 25,000 tagged and clipped fish have been released annually in recent years. A tagging program also exists in the Umpqua subregion at Rock Creek Hatchery, where approximately 64,000 tagged and clipped fish were released annually in recent years. Tagging programs within the Mid South subregion include the Coos and Coquille River hatchery CWT programs, where approximately 25,000 tagged fish have been released from each program through BY 2002. There are currently

no hatchery programs within the Coastal Lakes subregion. However, because of its geographical proximity to the Lakes subregion, the North Umpqua River Hatchery coho tagging program has been used to estimate ocean survival rates for the Lakes natural coho populations (Zhou 2000).

**Southern Oregon/Northern California MU (ORECAL)** – This MU includes the Southern Oregon/Northern California Coast (SONCC) Coho ESU which was listed as threatened under the ESA in 1997 (Good et al. 2005). This listing was reaffirmed in 2005. The ESU includes all naturally spawned populations of coho salmon in coastal streams between Cape Blanco, Oregon, and Punta Gorda, California, as well three artificial propagation programs: the Cole Rivers Hatchery, Trinity River Hatchery, and Iron Gate Hatchery coho hatchery programs. The Cole Rivers Hatchery on the Rogue River currently implements a DIT program, where release sizes have averaged 27,000 tagged fish per DIT group annually. Hatchery programs on the Klamath and Trinity Rivers currently release over 500,000 fish combined, annually, but tagging programs at these facilities were discontinued after BY 1992. There are currently no hatchery or wild index or production CWT releases from California. However, research and monitoring of the distribution, status, and trends of coho have been identified as priority recovery actions needed for the SONCC coho salmon ESU.

**Central California Coast Coho MU (CENCAL)** – This MU includes the Central California Coast Coho Salmon ESU which was first listed as threatened in October 1996 and then as endangered in June 2005. This ESU includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to and including the San Lorenza River in central California, as well as populations in tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system, as well as four artificial propagation programs: the Don Clausen Fish Hatchery Captive Broodstork Program, Scott Creek/Kind Fisher Flats Conservation Program, Scott Creek Captive Broodstock Program, and the Noyo River Fish Station egg-take Program coho hatchery Programs. The Noyo Station releases an average of 75,000 fish annually, none of which are tagged. Tagged fish have been released recently from the Warm Springs Hatchery on the Russian River, but this program is not considered an index program at this time. Retention of coho has been prohibited in ocean fisheries off California since 1994 and in fresh water recreational fisheries in the Klamath-Trinity Basin since 1997. There are currently no hatchery or wild index or production CWT releases from Central California, but research and monitoring of the distribution, status, and trends of coho have been identified as priority recovery actions needed for the Central California Coast coho salmon ESU.